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THE

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[THIRD SERIES.]

ART. XXV.—*The effect of Glaciation and of the Glacial Period on the present Fauna of North America;* by SAMUEL H. SCUDDER.

THE time has perhaps arrived when at least a beginning may be made in an investigation which shall show with some degree of exactitude just what amount of influence the Glacial Period has exerted upon the present distribution of animal life in North America. Within a few years, and with a degree of precision sufficient for our purpose, geologists have mapped the areas which were once completely buried beneath the northern ice-sheet, and which were then absolutely devoid of animal life. With the slow southward advance of the ice, animals were crowded southward; with its recession they advanced again northward to reoccupy the desolated region, until now it has long been repopulated, either with the direct descendants of its former inhabitants or with such limitations to the integrity of the fauna as this interruption of local life may have caused. Precisely what modifications may have resulted, what probable resemblance the present fauna bears to that which preceded it before the interruption of its occupancy of the whole area, is the problem before us, though we shall only attempt a first step toward its solution.

In considering this question it occurred to me that some light might be thrown upon the matter if one were to tabulate separately the animals of the eastern half of the continent now found (1) upon the area once covered by the ice-sheet and (2) upon the driftless area, using the mapped limits of the terminal moraine to separate the two regions; to discover how

many genera and species were common to both, and how many peculiar to each, of the two areas; and finally, to compare these results with those reached by a similar study of the existing fauna of somewhat equivalent areas upon the Pacific coast where, it is claimed, no continental ice-sheet covered the face of the country. Here one would have to choose somewhat arbitrarily a delimitation between the two areas, north and south, which should tolerably correspond climatically with that of the terminal moraine of eastern America. Accordingly, before beginning any tabulation, I selected the following areas for comparison: East of the Rocky Mountains, the "barren ground" of the high north, the immediate vicinity of the Rocky Mts. and the extreme south of Florida and Texas were left out of consideration, and the two areas were separated by the line of the great terminal moraine as mapped by Chamberlin. West of the Sierra Nevadas, the two areas were separated by the northern border of California, and the southern district was limited southwardly by the omission of the region south of Los Angeles; while the northern district was made to include the northern part of Washington and the southern portion of British Columbia, though drift covered, so as to embrace in the lists the numerous collections made on Vancouver Island and the adjoining main land.

Of course it is well understood that the fauna of eastern is far better known than that of western America; but this is no real obstacle, since the comparison is to be made in either section between the northern and the southern districts of that section only, and there no great inequality exists; the special point of enquiry is as to the relative faunal weight of the north, if the expression may be allowed, in the east, where the ground required complete reoccupancy, and in the west, where occupancy had not been interrupted.

This would furnish a gauge, as it were, of the effect of the Glacial Period upon the present faunal distribution of life. For if it should be found that the relative proportion of endemic northern genera and species was distinctly less in the east than in the west, and the relative number of genera and species common to north and south also less; then surely such relative poverty might properly be taken as a gauge of the insufficiency of the time that has elapsed since the glacial period for the fauna to have recovered its ancient territory. If, on the other hand, no sign of such poverty can be discovered, then we may fairly assume that the east has fully recovered from the shock of the Glacial Period, and that, excepting in minor points which special investigation would point out, the present distribution of life is much what it would have been had there been no Glacial Period. I may

venture to add that before beginning this enquiry I had no idea what the result of my tabulation would prove.

In the following discussion of the question, I shall limit myself to the use of insects, and indeed of a single order of insects, as subjects for illustration: not only because some limitation must be made in this place with so large a subject before us, but also, and principally, because insects may rightly be regarded as better tests than any other group of animals or than any group of plants, in nice questions of distribution either in space or time. This is not generally acknowledged, but a single pertinent illustration will suffice.

It is well known that as we pass upward in the Tertiary period there is a growing resemblance of the animals and plants of its different subdivisions to those living at the present time; a resemblance both in general and in particular, an increasing percentage of forms regarded as identical or nearly identical with existing types being found as one passes from the Eocene to the present time. Furthermore the plants and (leaving the mammals out of account) the known animals of the Quaternary are, with extremely rare exceptions, identified altogether with those now living. Nearly all the mammals are extinct. Now, although the main broad features of insect life appear to have been much the same in the early Tertiary as now, not only has not a single Tertiary insect been shown to be living at the present day, whether in Europe or America, but a considerable proportion of Quaternary insects have also been described as extinct. It is true that a few, a dozen or two, Tertiary insects have been listed as belonging to existing forms, but in each such case the determination has been made by one not conversant with insects, or else with no statement of the basis or terms of comparison.

As to the Quaternary insects, I find in Europe 80 Coleoptera which have been studied with more or less care; of these 13 are treated as extinct and 67 identified more or less confidently with existing European forms. This number however, it should be insisted upon, is made up very largely of remains from peat bogs, which are relatively very recent. In our own country, 48 species of pleistocene Coleoptera have been described,* of which only a single one is regarded as probably identical with an existing form, three are specifically indeterminate and 44 are extinct, though in some cases intimately allied to forms now living. I add a list of these.

* Including five species from Hadley, Mass., described in an unpublished memoir.

List of described American Quaternary Coleoptera.

Name.	Locality.	Allied to	From	Resemblance.
Scolytidæ				
Hylastes squalidens	Scarboro, Ont.			
Tenebrionidæ				
Tenebrio calculensis	Greene's Cr., Ont.	T. molitor Linn.	Eur., N. Amer.	general
Chrysomelidæ				
Saxinis regularis	Hadley, Mass.	S. saucia LeC.	Pac. coast to Color.	general
Donacia stiria	Scarboro, Ont.	D. porosicollis Lac.	Lake Sup., N. Engl.	general
pompatica	" "	D. pubicollis Saffr.	Illinois	close
elongatula	Hadley, Mass.	D. lignitum Sord.	Ital. Quaternary	close
Scarabæidæ				
Aphodius præcursor	Port Kennedy, Pa.	A. ruricola Melsh.	Anticosti to La.	close
Phanæus antiquus	" "	A. pluto Har.	Ariz, Mex.	close
Chœridium ebeninum	" "			
Elateridæ				
Corymbites æthiops?	Hadley, Mass.	(Recent)		
Fornax ledensis	Greene's Cr., Ont.	F. calceatus Say	Canada; Mass.	close
Byrrhidæ				
Byrrhus ottawaensis	" "	B. geminatus LeC.	Lake Sup., N. H.	very close
Staphylinidæ				
Arpedium stillicidii	Scarboro', Ont.	A. cribratum Fauv.	Michigan	general
Geodromicus stiricidii	" "	G. nigrita Müll.	North. U. S.; Can.	distant
Bledius glaciatus	" "	B. brevidens LeC.	New York	close
Oxyporus stiriacus	" "			
Lathrobium interglaciale	" "	L. grande LeC.	Lake Sup. to N. Car.	general
Hydrophilidæ				
Hydrochus amictus	Cleveland, O.	H. subcupreus Rand.	Lake Sup., southw.	general
Helophorus rigescens	" "	H. tuberculatus Gyll.	North. U.S.; Scandin	general
Dytiscidæ				
Dytiscidæ sp.	Hadley, Mass.	Matus bicarinatus Say	Canada to Fla.	possible
Carabidæ				
Chlænius punctulatus	Port Kennedy, Pa.	C. laticollis Say.	N. Y. to Fla.; Ariz.	close
Cymindis aurora	" "	C. americana Dej.	New York	close
extorpescens	Hadley, Mass.	C. elegans LeC.	Mass.; Fla.	general
Platynus casus	Scarboro', Ont.	P. rubripes Zimm.	Mid. St. to Kansas	general
hindei	" "	" "	"	general
halli	" "	P. crenistriatus LeC.	Western U. S.	general
dissipatus	" "	"	"	distant
desuetus	" "	"	"	close
harttii	" "			
dilapidatus	" "	P. maculicollis Dej.	Oreg.; Calif.; Ariz.	general
Dicælus alutaceus	Port Kennedy, Pa.	D. dilatatus Say.	U. S. E. of Gr. Plains	close
sp.	" "	D. elongatus Bon.	"	general
Pterostichus abrogatus	Scarboro', Ont.	P. herculaneus Mann.	Pac coast; Brit. Am.	close
dormitans	Cleveland, Ohio.	P. lætulus LeC.	California	very close
destitutus	Scarboro, Ont.	P. sayi Brullé	Atl. and west. St.	close
fractus	" "	"	"	distant
destructus	" "	P. patruelis Dej.	Mid. St.; N. York	very close
gelidus	" "	P. hudsonicus LeC.	Hudson Bay	close
lævigatus	Port Kennedy, Pa.			
sp.	" "			
Patrobus gelatus	Scarboro', Ont.	P. septentrionis Dej.	N. Eur.; Arc. Amer.	very close
Bembidium glaciatum	" "	B. longulum LeC.	Lake Sup.; N. York	close
fragmentum	Cleveland, Ohio.	B. constrictum Lec.	New England	close
Loricera glacialis	Scarboro', Ont.	L. cærulescens Linn.	Bor. Am. & Eur.; Sib.	general
lutosa	" "			
Elaphrus irregularis	" "	E. viridis Horn	California	close
Cychrus wheatleyi	Port Kennedy, Pa.	C. viduus Dej.	Pennsylvania	general
minor	" "	C. andrewsii Harr.	Centr. Atl. states	general

It should be noted that this series, in contradistinction from the European, does not include any forms from the peat, regarding which nothing has yet been published. I may however add that I have studied a very large collection of peat insects from Massachusetts and have so far separated over 60 species of Coleoptera, of which 27 are identified with existing forms, 10 are probably the same as species now living, and only one, a Hydrocanthus, is certainly different from anything yet known. The study of the remainder has not been concluded.

In our own country, then, the coleopterous fauna of the peat is practically identical with that now living; while that of deposits further removed from the present, but laid down *since* the beginning of the Glacial Period, is practically entirely extinct. When the early Quaternary Coleoptera of Europe have been attentively studied, I believe that the same conclusion is likely to be drawn from them. It thus appears that in this country the Coleoptera are at least as sensitive standards of climatic or faunal changes as are the Mammalia, which have hitherto been regarded as the only group of animals any considerable portion of which have become extinct in quaternary times; and that they are more sensitive tests than other groups of animals or than plants.

Having for these reasons selected insects as the best subjects for investigation, I have further restricted myself to Coleoptera, as the order which has been longest studied, is best known, and is most numerous in described species, the greater part of which have had the benefit of monographic revision. The main difficulty, that the catalogues give no indication of the geographical distribution of the different species, has been completely removed by the signal kindness of my friend Mr. Samuel Henshaw, who has liberally allowed me the freedom of his manuscript catalogue, in which he has placed against each species every published indication of special locality or general range, besides those furnished by his own knowledge.

The following table gives in detail for each family of Coleoptera the result of my examination of Mr. Henshaw's catalogue, and includes over 7500 species. For brevity, I have designated the drift-covered area of the east as D; the driftless area of the same as E; the northern portion of the Pacific region as N; and the southern as S. The first figure in each column indicates the number of genera, the second of species. The sign $>$, as in S$>$N, indicates that the numbers in that column are the number of genera found in S and not occurring in N, and the number of species in those same genera occurring in S. The sign $+$, as in S$+$N, means the number of genera common to both S and N and the number of species

of those genera occurring in one or the other or in both (which is usually fully twice the number of species common to both). Although beside my immediate purpose I have added the middle set of three columns for the sake of comparison.

Table of the regional distribution of North American Coleoptera.

Families.	S>N	S+N	N>S	N>D	N+D	D>N	D>E	D+E	E>D
Cicindelidæ	2:2	2:23		1:2	1:32	1:1		2:73	1:1
Carabidæ	24:39	22:172	5:6	3:4	26:382	47:132	12:15	64:679	33:69
Amphizoidæ		1:3		1:3	1:3				
Haliplidæ	2:2	2:2			2:9			2:13	
Dytiscidæ	8:12	10:51	2:2		12:129	13:24	2:3	23:171	3:3
Gyrinidæ	2:2	1:5			1:18	2:5	1:1	2:6	
Hydrophilidæ	6:7	4:28			4:33	10:32	3:4	12:84	5:5
Leptinidæ					2:2	2:2	2:2	2:2	
Silphidæ	1:1	10:22	4:4	6:9	10:60	6:13		13:62	4:4
Scydmænidæ	1:1	1:4			1:15	5:6	3:4	3:29	1:1
Pselaphidæ	3:3	2:10	1:1	1:1	15:104	14:35	1:1	14:103	11:14
Staphylinidæ	24:54	21:142	9:9	9:9	22:311	55:138	13:20	61:519	33:51
Trichopterygidæ		3:17		1:1	2:14	3:6		5:29	5:6
Sphæriidæ	1:1	1:1							
Scaphidiidæ	1:1	1:1			4:9	4:9	1:1	3:14	2:3
Phalacridæ	1:2	1:1	1:1		2:8	1:5		3:24	6:11
Corylophidæ	2:2		1:1		1:1	5:9	3:4	3:10	
Coccinellidæ	2:2	9:37	1:1	1:1	9:66	11:20	2:2	18:109	2:3
Endomychidæ	2:4	1:3			1:3	6:6		7:9	3:8
Erotylidæ	1:2	1:1			1:11	6:16		7:42	
Colydiidæ	4:4	5:11	1:1	4:5	2:3	8:9		10:20	10:14
Rhyssodidæ	1:2		1:1		1:2	1:1		2:2	
Cucujidæ	3:8	3:4	1:1	2:2	2:5	6:18		8:35	6:8
Cryptophagidæ	2:3					7:9	1:1	6:14	2:2
Mycetophagidæ	1:1	2:4			2:8	4:7		6:20	
Dermestidæ	5:10	3:8			3:11	6:10		9:27	3:3
Histeridæ	4:5	3:21			3:58	8:16		12:128	7:8
Nitidulidæ	3:4	4:9	2:2	2:2	4:20	14:30		18:60	6:6
Latridiidæ	4:15					4:22	2:2	3:37	2:2
Trogositidæ	2:2	3:7	1:2		3:16	4:8	1:1	6:24	2:2
Derodontidæ					1:1	1:1		1:1	
Byrrhidæ	2:7	1:3	2:2	1:2	2:5	4:12	4:12	2:12	1:1
Georyssidæ	1:1					1:1		1:1	
Parnidæ	2:2	1:4			1:9	5:10		6:24	2:2
Heteroceridæ		1:2			1:9			1:13	
Dascyllidæ	6:6	1:2	2:2	1:1	2:8	9:13	3:3	8:24	2:2
Rhipiceridæ	1:1					3:5		3:5	
Elateridæ	14:18	17:100	3:4	1:1	19:200	29:53	5:8	42:269	14:20
Throscidæ	1:1	1:5			1:6	1:2		2:11	
Buprestidæ	6:14	6:37	1:1	1:1	6:61	12:41	2:2	16:146	9:14
Lampyridæ	8:14	8:36		1:1	7:66	18:43	2:2	23:13	10:11
Malachidæ	5:9	5:35		3:4	1:8	5:9	1:1	6:35	5:8
Cleridæ	4:5	4:12			4:17	11:20	2:4	13:53	3:4
Ptinidæ	15:23	4:9	1:1		4:13	22:36	2:3	24:77	12:18
Cupesidæ			1:1	1:1		1:2		1:2	
Lymexylidæ						3:3	3:3		
Cioidæ	1:1					3:6		3:11	
Sphindidæ	1:1					3:3	3:3		
Lucanidæ		3:8		1:1	2:6	3:6		5:10	
Scarabæidæ	14:22	8:46	2:3	1:1	9:80	31:80	3:3	37:247	16:24

[TABLE continued.]

Families.	S>N	S+N	N>S	N>D	N+D	D>N	D>E	D+E	E>D
Spondylidæ		1:1			1:1	1:1	1:1	1:2	1:1
Cerambycidæ	27:32	22:90	12:14	8:8	23:170	55:95	8:11	67:258	51:74
Chrysomelidæ	20:30	21:75	8:12	3:4	25:144	40:95	6:8	60:431	22:34
Bruchidæ	2:9					1:7		1:32	3:4
Tenebrionidæ	26:37	12:54	4:4	9:15	8:33	22:30	5:5	28:97	34:72
Aegialitidæ	1:1	1:1							
Cistelidæ	2:3					7:22		7:33	2:6
Othniidæ		1:1						1:2	1:2
Lagriidæ								1:1	1:3
Melandryidæ	1:1	3:6	2:2	2:2	5:11	23:33	7:8	19:37	3:3
Pythidæ	5:5		1:1	1:1	1:1	5:5		2:3	1:2
Oedemeridæ	3:3	2:6	1:1		3:9	3:3	1:1	5:12	2:3
Cephaloidæ			1:1		1:3	1:2			
Mordellidæ	2:4	1:3			1:4	2:14		4:100	3:4
Anthicidæ	3:16	1:6	1:1	1:1	1:6	6:35	1:1	6:69	4:7
Pyrochroidæ			1:1		1:3	3:3	1:1	3:7	
Meloidæ	7:11	4:33		1:4	4:25	5:8		8:69	7:20
Rhipiphoridæ	2:3					3:11		3:19	
Stylopidæ						2:2	1:1	1:1	
Rhinomaceridæ	1:1	1:3			1:2			1:2	
Rhynchitidæ	1:1	1:5			1:3	3:7		4:14	
Attelabidæ					1:3	1:3		1:4	
Byrsopidæ								1:1	
Otiorhynchidæ	12:16	6:11	3:4	9:12		11:15	3:4	8:13	23:33
Curculionidæ	17:22	16:77	10:11	5:5	19:138	52:80	14:19	56:411	28:44
Brenthidæ								1:2	1:1
Calandridæ	6:7	2:7			3:19	5:7		7:36	13:17
Scolytidæ	1:1	9:34	2:2		10:58	12:22	2:2	22:99	4:5
Anthribidæ	2:2		1:1		1:1	9:11	2:2	8:18	7:10
Totals	334:521	281:1300	88:101	81:104	307:2355	690:1446	129:169	844:5072	432:673

Translating these totals into percentages we shall reach the following figures:

Districts.	S>N	S+N	N>S	N>D	N+D	D>N	D>E	D+E	E>D
Percentages	48:27	40:68	12:5	8:3	28:60	63:37	9:3	60:86	31:11

Or, if we place the percentages of the west and the east in parallel columns, we shall have the following:

	West	East
North	12 : 5	9 : 3
In common	40 : 68	60 : 86
South	48 : 27	31 : 11

Here it will be seen that in the northern percentage of both genera and species, the East lags a little behind the West, but it is only a very little, and it is much more than made up by the considerably larger percentage in the East of the genera common to North and South.

I have also tabulated the species reported as found common to the northern and southern districts on each side of the continent and find that about 16 per cent of all the western species are common to the two districts, while about 35 per cent of all the eastern are common to the drift-covered and driftless areas. I append a table of these numbers. One difference between this table and the previous one is that here the common species form the base, while in the previous one the common genera form the base; hence a genus represented in the two districts, but only by *distinct* species, does not appear in this table, but only in the previous one. Seven families in which there are no species recorded as found in two regions are omitted from the list.

Table of the species common to pairs of regions.

Families.	S+N	N+D	D+E	Families.	S+N	N+D	D+E
Cicindelidæ	2:5		2:22	Throscidæ			2:5
Carabidæ	20:46	14:25	62:245	Buprestidæ	5:10	4:6	16:62
Amphizoidæ	1:1			Lampyridæ	5:6	3:3	22:65
Haliplidæ			2:6	Malachidæ	3:3		5:12
Dytiscidæ	8:12	4:7	22:67	Cleridæ	2:3	2:2	12:18
Gyrinidæ		1:2	2:10	Ptinidæ	3:3		23:28
Hydrophilidæ	4:6	2:2	11:37	Cupesidæ			1:2
Silphidæ	13:17	7:12	15:43	Cioidæ			3:3
Scydmænidæ	1:1		2:7	Lucanidæ	3:3		5:8
Pselaphidæ	1:1		14:36	Scarabæidæ	6:9	2:3	36:106
Staphylinidæ	15:29	13:27	57:189	Spondylidæ	1:1	1:1	1:1
Trichopterygidæ	1:1		3:5	Cerambycidæ	17:20	12:13	66:155
Scaphidiidæ			3:7	Chrysomelidæ	15:19	12:14	59:164
Phalacridæ	1:1		2:5	Bruchidæ			1:7
Corylophidæ		1:1	3:5	Tenebrionidæ	10:14	1:1	28:45
Coccinellidæ	8:10	6:7	17:45	Cistelidæ			7:11
Endomychidæ	1:1		7:8	Lagriidæ			1:1
Erotylidæ			7:20	Melandryidæ	1:1	2:2	19:26
Colydiidæ	3:3	1:1	10:11	Pythidæ		1:1	1:1
Rhyssodidæ			2:2	Oedemeridæ			4:5
Cucujidæ	3:3		8:19	Mordellidæ	1:1		4:31
Cryptophagidæ			6:6	Anthicidæ			5:24
Mycetophagidæ	1:1	1:1	6:12	Pyrochroidæ		1:1	2:2
Dermestidæ	3:5	3:3	8:16	Meloidæ	3:4		7:15
Histeridæ	2:5	1:1	11:51	Rhipiphoridæ			1:5
Nitidulidæ	4:4	4:4	18:33	Stylopidæ			1:1
Latridiidæ			3:6	Rhinomaceridæ			1:1
Trogositidæ	3:3	1:1	6:16	Rhynchitidæ	1:1	1:1	4:8
Derodontinæ			1:1	Attelabidæ			1:5
Byrrhidæ	1:2		1:1	Byrsopidæ			1:1
Georyssidæ			1:1	Otiorhynchidæ	5:5		6:6
Parnidæ			6:13	Curculionidæ	10:16	7:7	47:117
Heteroceridæ	1:1	1:1		Brenthidæ			1:1
Dascyllidæ		1:1	7:12	Calandridæ	1:1	1:1	6:16
Rhipiceridæ			3:5	Scolytidæ	7:10	6:6	21:39
Elateridæ	9:14	10:15	41:119	Anthribidæ		1:1	6:7
				Totals	205:302	128:174	794:2083

These figures indicate, it seems to me, that on the whole the fauna of the East has nearly or quite recovered from its enforced removal from the northern States and Canada at the time of the Glacial Period, and that whatever influence the past existence of a Glacial Period may now exert upon the distribution of animal life in North America should be sought only in minor features, such as the remnants of boreal faunas lingering in favorable spots amid temperate surroundings, and the similar features induced by the latitudinal trend of our great mountain chains.

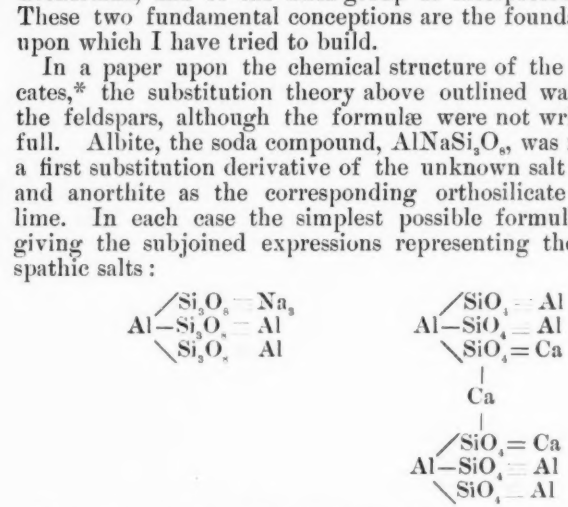
ART. XXVI. — *The Constitution of the Zeolites;* by F. W. CLARKE.

THE obvious relationship of many zeolites to the feldspars has long been recognized as a probable key to their constitution; and yet, so far as I am aware, no systematic theory of the connection between the two groups has been put forward. Partial work, indeed, has been done; as by Streng in his study of chabazite, and by Fresenius in his interpretation of phillipsite and harmotome; but a general explanation of the zeolites all together is still wanting. Much evidence, however, has accumulated with reference to the problem; such as that derived from the practical dehydration of the minerals, their modes of decomposition when fused, their synthetic formation, their changes under the influence of reagents, and so on; and the purpose of any exhaustive discussion of their nature should be to bring all these lines of testimony, all these varied data, into convergence. No system of constitutional formulæ can be valid unless it fulfils these conditions. It is possible, of course, to seek for too great a generality, and so to force an apparent harmony where real relations do not exist. To avoid this danger, it seems necessary to admit at once that all zeolites are not of feldspathic origin; some few are compounds of quite a different type; but most of the members of the group are easily represented by one general set of expressions, which apply to the feldspars as well.

The theory of the zeolites which is developed in the present paper, is a direct outgrowth and sequence of the views which I have published of late years concerning the micas, the chlorites, and various other minerals, and it is based upon the same principles. The complex or apparently complex aluminous silicates are regarded as generally being substitution derivatives of simple normal salts, such as $Al_4(SiO_4)_3$, $Al_4(Si_2O_5)_3$, etc.; a conception which brings to light many important rela-

tions, and which seems to be fully justifiable from all points of view. The acid radicals SiO_4 and Si_3O_8 are also regarded as mutually replaceable, the one by the other; a belief which may now be looked upon as fairly well established by the evidence of the feldspar and scapolite groups, as studied by Tschermak, and of the mica group as interpreted by myself. These two fundamental conceptions are the foundation stones upon which I have tried to build.

In a paper upon the chemical structure of the natural silicates,* the substitution theory above outlined was applied to the feldspars, although the formulæ were not written out in full. Albite, the soda compound, $AlNaSi_3O_8$, was regarded as a first substitution derivative of the unknown salt $Al_4(Si_3O_8)_3$, and anorthite as the corresponding orthosilicate containing lime. In each case the simplest possible formula is tripled, giving the subjoined expressions representing the two feldspathic salts:



From these formulæ the formulæ of many zeolites are easily derived; providing we assume that the soda salt may be replaced by its equivalent ortho-compound, and the calcium salt by the corresponding trisilicate. The sodium ortho salt would be isomeric with nepheline; but the calcium compound containing Si_3O_8 is purely hypothetical. Upon this basis, if we temporarily regard all water in the zeolites as water of crystallization, and represent the groups SiO_4 and Si_3O_8 by the general symbol X, the greater number of the minerals under consideration fall easily into two groups, having the following generalized formulæ:

$$1.\ \begin{cases} Al_6X_6R'_6, \text{ n. aq., } + \\ Al_3X_3R'_3, \text{ n. aq.} \end{cases}$$

$$2.\ \begin{cases} Al_4X_6R'_{12}, \text{ n. aq., } + \\ Al_2X_3R'_6, \text{ n. aq.} \end{cases}$$

For the first group, with varying amounts of water, we have thomsonite, gismondite, edingtonite, phillipsite, harmotome, chabazite, levynite, gmelinite, hydronephelite, and offretite.

* U. S. Geological Survey, Bulletin No. 60, 1887–88.

In the second group we find foresite, laumontite, heulandite, epistilbite, brewsterite, scolecite, stilbite, faujasite, and natrolite. The two groups remain in this form, however, only so long as we ignore water, for when we begin to regard the latter as partly constitutional, several members of the first series must be transferred to the second. This point will be made clear farther on. The species above named may be individually considered as follows:

Thomsonite.—$Al_6(SiO_4)_6Ca_2 . 7H_2O$. This is equivalent to anorthite plus water, and according to Doelter thomsonite yields anorthite upon fusion. Commonly a part of the lime is replaced by soda, either one or two atoms being so replaceable. Sometimes, as in "mesole," there is an excess of silica, which is accounted for by small admixtures of trisilicate molecules, or Si_3O_8 groups. The dehydration experiments of Damour, Hersch, etc., indicate that $\frac{4}{7}$ of the water must be regarded as constitutional. This may be represented as bringing about a replacement of Al by $-Al=(OH)_2+H_2$. Hence the final formula should be written

$$Al_4(SiO_4)_6Ca_2(AlH_2O_2)_2H_4 . 3H_2O.$$

Gismondite.—Uncertain, but probably $Al_6(SiO_4)_6Ca . 12H_2O$, with part of the lime replaced by potash, and perhaps in some cases Si_3O_8 replacing SiO_4. It is stated that $\frac{1}{3}$ of the water goes off at 100°, if the remaining eight molecules are constitutional, four aluminum atoms would be replaced by $4(AlH_2O_2)+H_8$, giving the formula

$$Al_2(SiO_4)_6Ca_3(AlH_2O_2)_4H_8 . 4H_2O.$$

Edingtonite.—Probably $Al_6X_6Ba_3 . 12H_2O$, with X about $\frac{3}{4}SiO_4$ and $\frac{1}{4}Si_3O_8$. Barium partly replaceable by other bases. Mode of hydration undetermined. According to Lemberg edingtonite, or a compound like it, is artificially derivable from natrolite. Although edingtonite has the same total number of water molecules as gismondite, its crystallization is totally different; so that the ratio of crystalline to constitutional water is probably not the same for the two species.

Phillipsite.—$Al_6X_6CaR'_4 . 15H_2O$. R′ may be either Na or K, and the ratio between SiO_4 and Si_3O_8 is quite variable. Little, if any of the water can be regarded as constitutional.

Harmotome.—$Al_6X_6Ba_3 . 15H_2O$. Ratio of Si_3O_8 and SiO_4 commonly 1 : 1. A little Ba replaced ordinarily by H_2 or alkalies. Recognized generally as closely analogous to phillipsite.

Levynite.—$Al_6X_6Ca_2 . 15H_2O$. $SiO_4 : Si_3O_8 :: 3 : 2$. Slight replacements of lime by alkalies. About $\frac{1}{3}$ of the water appears to be constitutional, judging from Damour's experiments.

Chabazite.—Ranges from $Al_6X_6Ca_3 . 18H_2O$, to $Al_2X_2Na_2 . 9H_2O$, with $SiO_4 : Si_3O_8 :: 1 : 1$, giving apparently metasilicate ratios. On fusion, according to Doelter, gives silica and anorthite. In the lime salt four molecules of water and in the soda salt two molecules are to be considered as constitutional; giving the ultimate formulæ

$$Al_4X_6Ca_2H_4(AlH_2O_2)_2 . 14H_2O,$$
$$Al_2X_2Na_2H_2(AlH_2O_2) . 7H_2O$$

Gmelinite.—$Al_2X_2Na_2 . 9H_2O$, or like the non-calcic chabazite; but with $SiO_4 : Si_3O_8 :: 1 : 2$. Two molecules of water are probably constitutional.

Hydronephelite.—$Al_2(SiO_4)_2Na_2H . 3H_2O$. Clearly a derivative of nepheline.

Offretite.—The analysis by Gonnard agrees sharply with the formula—

$$2Al_2(Si_3O_8)_3K_2 . 8H_2O + Al_2(SiO_4)_3CaH . 8H_2O.$$

So much for the first group of zeolites, which is characterized by the perfectly uniform ratio of Al : X = 6 : 6 or 3 : 3, accordingly as bivalent or univalent bases predominate among the remaining metallic components. The second group is similarly defined by the ratio Al : X = 4 : 6 or 2 : 3; the water being the chief variable. In detail, the members of this group are as follows:

Foresite.—$Al_4(SiO_4)_6CaH_{10} . H_2O$.

Scolecite.—$Al_4(SiO_4)_6Ca_2H_8 . 2H_2O$. According to Doelter, yields anorthite on fusion. Converted into natrolite by the prolonged action of soda solutions, according to Lemberg. Loses about $\frac{1}{3}$ of its water at 300°, regaining the same in moist air.

Laumontite. — $Al_4X_6Ca_2H_8 . 4H_2O$. $SiO_4 : Si_3O_8 = 5 : 1$. Yields anorthite and a pyroxenic mineral on fusion. Loses about $\frac{1}{2}$ its water at 300°.

Heulandite.—$Al_4X_6Ca_2H_8 . 6H_2O$, with $SiO_4 : Si_3O_8 = 1 : 1$. According to Doelter, yields a "lime augite" on fusion, with silica. This observation may best agree with the metasilicate formula $Al_2Ca(SiO_3)_6H_4 . 3H_2O$, both formulæ being empirically identical, and both in accord with the behavior of heulandite upon dehydration.

Brewsterite.—Like heulandite, but with barium and strontium replacing lime.

Epistilbite.—Isomeric with heulandite, but with the water apparently more firmly combined. Perhaps a part of the Al is replaced by $AlH_2O_2 + H_2$.

Stilbite.—$Al_4X_6Ca_2H_8 . 8H_2O$, with $SiO_4 : Si_3O_8 = 1 : 1$. On fusion, behaves like heulandite, but sometimes yields anorthite. The variations in composition are probably due to variations in the ratio between the ortho- and trisilicate groups.

Faujasite. — $Al_4X_6Na_2CaH_8 . 15H_2O$. $SiO_4 : Si_3O_5 = 2 : 1$. Faujasite may also be represented as a salt of the acid $H_6Si_2O_7$, with the formula $Al_4(Si_2O_7)_5CaNa_2H_{14} . 12H_2O$. As the mineral does not gelatinize when decomposed by hydrochloric acid, it may not belong with the orthosilicates.

Natrolite.—$Al_2(SiO_4)_3Na_2H_4$. Doubtful as regards the character of its water. Yields nepheline on fusion, the latter mineral being $Al_2(SiO_4)_3Na_3$, with occasional replacements of SiO_4 by a very little Si_3O_5.

A careful scrutiny of the foregoing formulæ will show that, so far as our present data go, they fulfill all the conditions laid down at the beginning of this article. They agree with the published analyses, and account fully for their variations, and in type they correspond to the two feldspathic molecules of which the configurations have been given. They differ chiefly with respect to hydration, and these differences are now intelligible. Furthermore, several of the species yield anorthite when fused, which connects the formulæ given with the types assumed, and also with the probable genesis of zeolites from feldspars. Their deficiencies correspond to deficiencies in evidence, and they suggest the lines of investigation by which they may be finally established or discarded. If the formulæ do no more than to perform the last named function, they have a value which entitles them to consideration. Neglecting the distinction between crystalline and constitutional water, and omitting for sake of brevity the few barium-strontium salts, the normal zeolites, if I may call them so, can be tabulated as follows:

First Group.

Thomsonite	$Al_6(SiO_4)_6(CaNa_2)_2 . 7H_2O$
Gismondite.....	$Al_6(SiO_4)_6(CaK_2)_2 . 12H_2O$
Phillipsite.....	$Al_6X_6CaR'_4 . 15H_2O$.
Levynite	$Al_6X_6Ca_2 . 15H_2O$
Chabazite. A...	$Al_6X_6Ca_2 . 18H_2O$
" B...	$Al_3X_3Na_3 . 9H_2O$
Gmelinite	$Al_3X_3Na_3 . 9H_2O$
Hydronephelite .	$Al_3(SiO_4)_3Na_3H . 3H_2O$
Offretite	$Al_3X_3R'_3 . 8H_2O$

Second Group.

Foresite	$Al_4(SiO_4)_6CaH_{10} . H_2O$
Scolecite	$Al_4(SiO_4)_6Ca_2H_8 . 2H_2O$
Laumontite	$Al_4X_6Ca_2H_8 . 4H_2O$
Heulandite.....	$Al_4X_6Ca_2H_8 . 6H_2O$
Epistilbite	$Al_4X_6Ca_2H_8 . 6H_2O$
Stilbite	$Al_4X_6Ca_2H_8 . 8H_2O$
Faujasite	$Al_4X_6Na_2CaH_8 . 15H_2O$
Natrolite.....	$Al_2(SiO_4)_3Na_2H_4$

There still remain several zeolites to be considered, together with some allied minerals, which seem to be compounds of a different type from those represented in the preceding table. Two of these zeolites, ptilolite and mordenite, I have already discussed in a former paper;* and another, the more recently discovered laubanite, appears to be related to them. In ptilolite and mordenite we have salts of the bibasic acid, $H_2Si_2O_5$, while laubanite is a metasilicate of precisely similar type. The two first named minerals shade into each other as mixtures of certain fundamental salts, while laubanite is distinct. The formulæ are as follows:

Ptilolite and Mordenite.

$$Al\begin{cases}Si_2O_5\\Si_2O_5\end{cases}Ca \qquad Al\begin{cases}Si_2O_5-R'\\Si_2O_5-R'\end{cases} \qquad Al\begin{cases}Si_2O_5\\Si_2O_5-H\\Si_2O_5-H\end{cases}$$

$$+6H_2O \qquad +6H_2O$$

Laubanite.

$$Al\begin{cases}SiO_3\\SiO_3\end{cases}Ca \qquad Al\begin{cases}SiO_3\\SiO_3\\SiO_3\end{cases}Ca$$

$$+6H_2O$$

The relationship is so evident that it needs no farther explanation. Laubanite can be so written as to throw it into the normal series; but this constitution is certainly preferable.

Analcite, another zeolite, may be written $H_4Na_2Al_2X_8$, with $\frac{1}{6}$ of $X = Si_3O_5$. This would bring the mineral into the second group of normal zeolites, and into close relationship with natrolite. Analcite, however, is isometric, like the anhydrous leucite; and Lemberg has shown that by the prolonged action of alkaline solutions, analcite and leucite are mutually convertible the one into the other. Hence, the two species should be regarded as closely akin, and of similar type, and their simplest formulæ are as follows:

Leucite.

$$Al\begin{cases}=SiO_3\\SiO_3-K\end{cases}$$

Analcite.

$$Al\begin{cases}=SiO_3\\SiO_3-Na\end{cases}+H_2O$$

Both minerals, however, occur altered into feldspars; and it is an open question whether their formulæ should not be polymers of those given above, in order that the alterability may become interpretable. The same question arises with spodumene, a compound of similar formula, which splits up easily into albite and eucryptite. These points I shall consider elsewhere.

Three other minerals, which are sometimes classed as zeolites, but which contain no aluminum, are okenite, gyrolite, and apophyllite. These species are undoubtedly related; for

* This Journal, August, 1892.

apophyllite may be generated artificially from okenite, and gyrolite occurs in nature both as the parent and as a derivative of apophyllite. At New Almaden, apophyllite is the secondary mineral; while in Nova Scotia gyrolite appears to be formed by its alteration. All three species, considered as analogous in structure, are most simply represented as salts of the acid $H_6Si_2O_7$, and on this supposition they receive the following formulæ:

Okenite.	Gyrolite.	Apophyllite.
$Ca\begin{cases}Si_2O_7 . H_5\\ Si_2O_7 . CaH_3\end{cases}$	$Ca\begin{cases}Si_2O_7 . CaH_3\\ Si_2O_7 . H_4\end{cases}$	$Ca\begin{cases}Si_2O_7 . H_4(CaOH)\\ Si_2O_7 . H_4\end{cases}$
$Ca\begin{cases}Si_2O_7 . CaH_3\\ Si_2O_7 . H_5\end{cases}$	$Ca\begin{cases}Si_2O_7 . H_4\\ Si_2O_7 . CaH_3\end{cases}$	$Ca\begin{cases}Si_2O_7 . H_4\\ Si_2O_7 . H_4(CaOH)\end{cases}$

In apophyllite, the univalent $-Ca-OH$ is partly replaced by potassium, and the hydroxyl is often substituted by fluorine. The somewhat uncertain plombierite may also be represented as a member of the same group, having the formula $Ca_2(Si_2O_7)_3$ $Ca_3H_8 . 9H_2O$.

Since the object of this paper is merely to give a preliminary statement of the conclusions which I have reached, I have not thought it necessary to load down its pages with references to literature or with discussions of analyses. A large mass of data has been examined, and it is my intention to elaborate the subject to a considerable extent within the near future. When that is done the evidence will be presented with sufficient fulness.

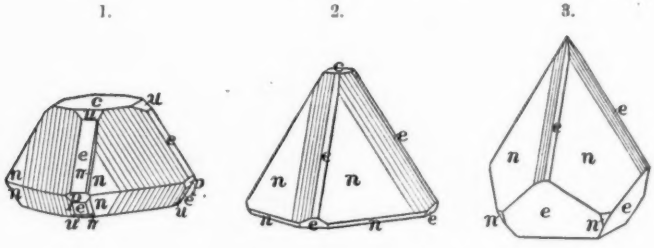
U. S. Geol. Survey, Washington, June 20, 1894.

Art. XXVII.—*On Hemimorphic Wulfenite Crystals from New Mexico;* by Charles A. Ingersoll.

The crystals that will be described in this communication were found by Mr. William E. Hidden* at the Turquoise mines in the Jarilla Mountains, Doña Ana County, New Mexico, and were sent to Professor S. L. Penfield in the fall of 1892. They were implanted upon a brown siliceous gangue and were described by Mr. Hidden as occurring in seams in trachyte, associated with quartz, pyrite, chalcopyrite, malachite, gypsum, jarosite and kaolin. They were said to be of quite rare occurrence, only a very few having thus far been found, and are of especial interest on account of their peculiar hemimorphic and pyramidally hemihedral development.

* This Journal, III, xlvi, p. 401, 1893.

These crystals were small, measuring from one to two millimeters in diameter, white in color, subtransparent, and of a decided adamantine luster. Before attempting to measure any of them a careful blowpipe examination was made, and the mineral was found to be Wulfenite. Three crystals were selected as best representing the different habits of the mineral, and one of these (fig. 1) was chosen for crystallographic measurement. This was quite perfect, prominently hemi-



morphic in development, and more highly modified than any of the others. Its faces yielded remarkably distinct reflections of the goniometer signal, thus furnishing very accurate measurements of the interfacial angles. The forms that were observed, together with their hemimorphic occurrence, are as follows:

c, 001, 0 above and below.	*e*, 101, 1-$\bar{1}$ above and below.
n, 111, 1 " " "	*p*, 20$\bar{1}$, 2-$\bar{2}$ below only.
u, 102, $\frac{1}{2}$-$\bar{2}$ " " "	π, 313, $\frac{1-3}{3}$ above and below.

Of the above forms *p* and π were here observed for the first time; moreover, they were found only on a single crystal (fig. 1).

The hemimorphic character of the mineral is shown in the occurrence of the *p* face, only in the lower portion of the crystal, as well as in the relative development of the other faces. The form π is present in the upper portion as a very narrow face, while below it is quite well developed. On all the crystals the lower *c* face is the larger, while the upper one is sometimes wanting (fig. 3). The development of the forms *n* and *e* on some of the crystals is very remarkable (figs. 2 and 3). A hemimorphic habit, similar to fig. 3, has already been observed by Breithaupt* on crystals from Berggieshübel in Saxony, which are described by him as being beautifully white, with adamantine luster.

* Handbuch der Mineralogie, II, p. 272, 1841.

The pyramidal hemihedrism is shown by a series of striations, resulting from an oscillatory combination of n with one of the adjacent e faces. This is found on all the crystals to the right of n only. Moreover, the form π is found only to the right of e. This development of hemihedrism in the pyramidal forms of Wulfenite is particularly interesting, since it has, hitherto, been observed chiefly in the prismatic zone.

The calculated angles in the following table were obtained from the fundamental measurement of Dauber,* $n \wedge n$, $111 \wedge \bar{1}\bar{1}1 = 131° 42'$, from which the length of the vertical axis, $c = 1{\cdot}5771$, is obtained.

	Measured.		Calculated.	
$n \wedge n$, $111 \wedge 1\bar{1}1$	80°	25′	80°	22′
$e \wedge e$, $101 \wedge \bar{1}01$	115	16	115	15
$e \wedge n$, $101 \wedge 111$	40	12	40	11
$u \wedge u$, $102 \wedge \bar{1}02$	76	20	76	31
$e \wedge u$, $101 \wedge 102$	19	20	19	22
$p \wedge p$, $20\bar{1} \wedge \bar{2}0\bar{1}$	144	31	144	50
$e \wedge p$, $10\bar{1} \wedge 20\bar{1}$	14	42	14	47
$e \wedge \pi$, $10\bar{1} \wedge 31\bar{3}$	15	42	15	43
$n \wedge \pi$, $11\bar{1} \wedge 31\bar{3}$	24	30	24	28
$\pi \wedge \pi$, $313 \wedge \bar{3}\bar{1}3$	117	56	117	56
$\pi \wedge \pi$, $313 \wedge 31\bar{3}$	62	8	62	4

In the above table the measured angles have been taken as the mean of four readings. No accurate measurements could be made on c, owing to its vicinal development. The occurrence of the new forms p and π is proved not only from the above measurements but from their positions in the correct zones.

It is probable that the isomorphous minerals, scheelite, powellite and stolzite are also hemimorphic; but as yet no forms have been observed which indicate this.

In conclusion the author wishes to express his thanks to Professor Penfield for assistance rendered during the course of this investigation.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, April, 1894.

* Pogg. Ann., cvii, p. 267, 1859.

Art. XXVIII.—*Notes on the Tertiary and later History of the Island of Cuba;* by Robert T. Hill.*

This paper is an abstract of a more extensive manuscript report made to Prof. Alexander Agassiz and is based upon a reconnoissance of most of the Island of Cuba, with the exception of the mountainous region of the Sierra Maestra the geology of which has been partially presented by Kimball in this Journal,† and studied contemporaneously with the writer's observations by Prof. Clarence King. My reconnoissance was accompanied by critical studies of certain typical localities at Havana, Matanzas, Villa Clara, Gibara, Baracoa and the vicinity of Cape Maysi.

The stratigraphy, age, and general relations of the rocks of Cuba have been set forth by De Castro,‡ and Salterain§ together with a good geologic map.

It is not necessary in this paper to dwell upon the details already presented. The geological structure of the Island consists of four stratigraphic units, to wit: (1) The Pre-Tertiary, Metamorphic and Igneous Foundation; (2) The Pre-Tertiary sedimentaries, mostly of Cretaceous age; (3) The Tertiary limestones; and, (4) The modern elevated coral reefs.

1. The Metamorphic and Igneous Foundation. The contemporary investigations of Prof. King in the Sierra Maestra will no doubt throw more light upon these formations than I can give.

These older rocks consist of diorites, serpentines, schists and granites as reported by Kimball from Santiago; of serpentines, green stone, porphyry and basic igneous rocks, fragments of which are brought down by the rivers of the north side of the east end of the Island; of serpentine and metamorphic rocks, with little quartz, as seen underneath the limestone in the vicinity of Villa Clara; and of serpentine, old volcanic material and tuffs, as seen back of Havana. They are exposed by erosion at various points throughout the island, but, with the exception of the Santiago region, seldom if ever, form the rocks of the immediate coast. They now underlie nearly every

* By permission of Prof. Alexander Agassiz through whose generosity the observations set forth in this paper were made possible.

† Geological Relations and Genesis of the Specular Iron Ores of Santiago de Cuba. This Journal, Dec., 1884.

‡ Pruebas Paleontologicas de que la Isla de Cuba ha Estado Unida al Continente Americano y breve idea de su Constitucion Geologica, por Don Manuel Fernandez de Castro. Discurso pronunciado en el cuarto Congreso internacional de Americanistas celebrado en Madrid en Setiembre de 1881.

§ Apuntes para una Description Fisico-geologica de las Jurisdieciones de la Habana y Guanabacoa, etc. por D. Pedro Salterain y Legarra, etc., Madrid, 1890.

part of the island at no great depth, and are exposed near both coasts in many cuts beneath the limestones. From their composition and occurrence there can be little doubt that they once formed an ancient land area almost as large as the present island which became almost or completely submerged during early Tertiary time. Wherever I have seen these rocks, at Villa Clara, Havana and near Baracoa, they have once been covered by the Tertiary limestones, but I cannot speak with certainty concerning the province of Santiago de Cuba, where, according to Kimball,* traces of limestone are preserved as high as 2,300 feet on the south side. On the north side, opposite Santiago, they are certainly overlapped far interiorward by the limestones.

Igneous rocks are rarely intrusive through the Tertiary limestone, no late igneous rocks having been seen by me except one small dike which intrudes into the folded Tertiary limestone near the water-works back of Havana. The presence of eruptives† and of sediments older than Tertiary, reported by DeCastro‡ and seen by me at a few points, and the unconformities testify that in pre-Tertiary time the old metamorphic floor protruded above the level of the sea as a land area, forming a nucleal region around and upon which the later formations were accumulated.

The pre-Tertiary sedimentaries.—Resting upon this metamorphic and igneous foundation at various places, there is a formation of stratified, non-fossiliferous sedimentary clays. These are older than the Tertiary limestone, but apparently immediately preceded them in origin. They have not great thickness and are without determinable fossils wherever I have observed them. In the Havana section a few feet only are exposed beneath the old limestone in contact with the underlying tuffs. They are here green in color and somewhat unctuous.

In traveling overland eastward toward Villa Clara, the limestones extend to beyond Colon; but between that place and San Pedro they are eroded through down to the underlying clay formation which extends from there continuously eastward to Villa Clara, being best exposed in the railway cut at Esperanza. Here the railway has cut across a low anticline of clays which show well-defined stratification and alternate strata of softer and harder beds. These clays are folded and slightly faulted in places.

* This Journal, Dec., 1884.

† The word eruptive is herein used in the restricted sense of igneous material which has protruded to the surface.

‡ Op. cit.

I could find no fossil remains except one poorly preserved plant impression, a monocotyledon, which, with the general character of the material gave the impression that these clays were deposited when the conditions of sedimentation were far different from those of the present. I cannot say positively that the Esperanza clays are identical with the clays at Havana, but they both occupy the same relative position between the limestones and the metamorphic formation, and are both exposed by the erosion of the overlying limestone. De Castro refers the clays of Esperanza to the Cretaceous period; upon what ground except stratigraphic position, I cannot say. He reports other Mesozoic sedimentaries at both ends of the Island together with Ammonites and Radiolites which would clearly indicate the occurrence of Cretaceous deposits in Cuba, but I had not time to study these.

The White Limestone Formations.—In strong contrast with the Esperanza clays and the older metamorphic floor are the Tertiary and later limestones which cover them, and which are the predominant geologic feature of Cuba.

The study and classification of the limestone group is difficult owing to the folding, induration, erosion, the thick covering, in places, of soil and vegetation, the universal alteration they have undergone through solution and internal changes, and the general concealment by tufaceous incrustations of well defined stratification planes and partings. They are clearly divisible into two general groups—the older and the newer. The latter consist mostly of unfolded rocks of undoubted coral-reef origin, and occur on the lower levels adjacent to the coast, while the former, if of coral-reef origin, have lost all characteristic proof of such origin, are undulated and folded and constitute the uplands and high coastal scarps against and around which the later coral rock was deposited.

The Older Limestones.—The more ancient limestones and accompanying beds constitute all the limestones of the Island seen by me above an altitude of 100 feet. They are very diverse in texture and composition. Where good exposures are obtainable they usually exhibit well defined stratification and separation planes, never seen in the undoubted reef rock, sometimes alternating with more marly or very slightly arenaceous layers. While it is in general cellular, a cubic foot of it in any locality exhibits great irregularity in hardness and compactness. There are spots so hard and crystalline that it is difficult to break them with a hammer; other portions are firmly crystalline and banded; while again there are soft, pulverulent layers. All of this difference in structure is of secondary origin, the result of alteration. In some places the cellular cavities are many feet deep, often extensively cavern-

ous, while the remaining thin partitions are indurated into sharp edges of coarsely crystalline marble—a surface induration which I have also often noticed in the chalky Cretaceous limestones of Texas.

On the resisting summit points the rock is hardened and worn into Karrenfelder, while the steeper bluffs are thickly coated with tufaceous deposits. Great caverns abound in these rocks in many parts of the island. So completely has the work of solution and interstitial change gone on that the original nature of the rock is nowhere well preserved. It nowhere exhibits the enormous proportions or abundance of coral remains so apparent in the reef rock, but on the other hand there is an abundance of casts and moulds of molluscan shells, and I seriously doubt if it was originally a reef rock, as has been alleged.

I do not think the occasional traces of coral proves reef rock origin, for all corals are not reef building and the molluscan remains are far more abundant than those of corals. Neither can they be called chalks, although very foraminiferous in places, for they are too coarsely crystalline, and lack that fineness and uniformity of texture seen in the chalky limestones which I have had considerable experience in studying. In places at their basal contact they are certainly detrital, showing at the reservoir south of Havana, where they are in contact with the older series of clays and serpentines, a distinct conglomeritic structure, largely composed of shell fragments and beach wash. Near Villa Clara they contain very small fragments of igneous material derived from the older rocks which they buried. The limestones also contain alternations of other material which is clearly not of reef rock origin, such as the great beds of fine, siliceous and argillaceous material as noted at Matanzas and seen from thence east to Baracoa, forming thick strata of yellow material, containing, at least at Baracoa, Miocene mollusca. These slightly arenaceous yellow beds outcrop at Nuevitas, Gibara and many other places along the coast, and are included between thicker strata of limestone, and I think they are underlain by several hundred feet of the latter material, and belong above the limestone capping Junki and the Yumuri bluffs. These yellow beds underlie the Seboruco reef at Baracoa, and are capped by a thick stratum of old limestone back of the city; the harbor is largely formed by their undermining; they are also well developed beneath the old reef points of Mata Bay.

A peculiar rock material in the old limestone series at Baracoa and not seen elsewhere is a hill of almost vertically stratified siliceous material, which at first sight resembles gray chalk, but has the light specific gravity of some of the diato-

maceous earths. Under the microscope this material is found to be largely composed of siliceous remains of minute Radiolarians. It is distinctly stratified, and contains occasional thin layers of a gray blue clay, and some secondary flint, in the form of nodules. It has clearly undergone great disturbance, as shown by the vertical arrangement of its beds, and apparently lies below the yellow beds, which are Miocene. The reservoir for the village water works is located upon the single hill where it outcrops on the southwest side of the harbor. The beds are over 500 feet in thickness; and I think they overlie the oldest of the limestones, but could not ascertain this with certainty. Neither this material nor the yellow beds which together constitute at least 500 feet of the Tertiary series, can be classified as of coral-reef origin.

In many places the Tertiary beds are distinctly stratified, as seen in the Castillo Principe plateau west of Havana, where they contain alternations of stratified argillaceous layers. Likewise at Matanzas, the older limestones exhibit every character of *sedimentary* deposition with molluscan remains, rather than of coral reef growth. At Baracoa, Nuevitas and elsewhere on the west coast the limestones are not only stratified, but they alternate with Miocene argillaceous and arenaceous beds of a yellow material, containing great numbers of molluscan fossils. In fact, I do not believe that any of the Tertiary limestones are of reef rock origin, but they are mostly organic and chemically derived marine sediments mixed with the calcareous debris of the life of the ocean's slopes, and rarely with an almost imperceptible proportion of the finer detrital sediments of the local land.

While these limestones and alternating beds have a great areal extent it would be a mistake to assign to them a proportionate thickness; accurate measurements will not make their thickness anywhere greater than 1000 feet. I estimated from the dips in the Rio Armendaris section that it was there from 800 to 1000 feet; the incomplete section in the cañon of the Yumuri of Matanzas reveals 800 feet; the cañon of the Yumuri of Baracoa shows 600 feet; the summit of Junki displays less than 1000 feet; while the section from 14 kilometers south of Havana to Batabano is not over 1000 feet. In fact, these limestones may be said to constitute a comparatively thin veneering over the old metamorphic floor.

The old limestone formations occur from end to end of the island and extend in many places completely across it down to the water level. Their continuity is interrupted only by erosion in spots along the central region. Only the low coast adjacent to the sea level is covered by later deposits. De Castro's geologic map of Cuba has, in an excellent manner,

shown the general disposition of the old limestones. In places as between Mata and Yumuri they form the north wall of the coast. They cap the highest eminences of the island seen by me, overlooking all other rocks, being alone overreached in altitude by the Sierra Maestra. Their close proximity to the north coast and their abrupt protuberance above the newer formations has an important bearing on the history of the island as a whole. So extensive is this old limestone formation and so abruptly does it rise above the coast, that if all the coastal formations were stripped away or if the island should subside for 100 feet its superficial extent would hardly be perceptibly diminished, or its outline materially altered.

The greater part of these limestones examined by me are, as stated by Salterain and De Castro, of Eocene, Miocene, and Pliocene age. In the Armendaris section near Havana, they include both Eocene and Miocene as has been asserted by De Castro and others, and as shown by my collections. At Baracoa the upper layers are Miocene. De Castro, La Sagra and others have recognized the Tertiary age of these limestones and their distinctness from the modern reef rock.

The Post-Tertiary Folding.—The chief feature which separates the older limestone into a distinct system from the modern reef rock is the stratigraphic unconformity between them, and the fact that the former have undergone great folding and disturbance prior to the deposition of the latter, which are always sub horizontal. In no locality have I seen the newer reef rock folded or seriously pitched, but the older limestone is frequently tilted at an angle of 45° or even vertically as at Baracoa, and sometimes folded into anticlines as back of Havana; it presents every degree of folding and disturbance in the numerous railway cuts between Havana and Matanzas, at Villa Clara, Yumuri and elsewhere. In fact it is seldom if ever sub-horizontal on the north coast, and the later deposits are entirely unconformable with it. The general lay of the old limestone is that of a low anticlinal whose axis corresponds with that of the island, accompanied by folds more greatly developed along the north coast. This folding clearly took place at or soon after the close of Tertiary time, and prior to the deposition of the Post-Tertiary formations and elevations to be described, and indicates one of the most important epochs in the geological history of Cuba, representing as it does an orogenic disturbance not observed in continental North American history. There is evidence at Havana that there was some eruptive action at this epoch, dykes having been seen there which protruded through the Tertiary.

The Seboruco or Elevated Coral Reefs.—In strong contrast with the older or Tertiary limestones is the modern group of

limestones of undoubted coral reef origin which border the coast in most places, or form small coral islets adjacent thereto, locally known as Seboruco.*

The elevated reef rock can always be recognized by the perfection and abundance of well preserved remains of reef making corals which form the greater proportion of the mass and by the absence of lamination or bedding planes. The formation averages about thirty feet in thickness, and usually extends inland only a short distance, often only a few yards, as on the northwest point of Moro Point, or not over an eighth of a mile as at Baracoa.

The Seboruco is a topographic as well as a stratigraphic feature, for its surface which was that of the old submerged reef represents a bench gently sloping to the sea; it has neither been covered by later deposits nor greatly denuded. It usually forms at the surf line a cliff about fifteen feet in height, against which the surf beats with great force, wearing deep indentations. The spray breaking over the summit produces the surface induration which is visible wherever rain or other moisture falls upon the hot limestones. This induration at Baracoa, for instance, has converted the reef rock in spots into a coarse saccharoidal marble, and aided in the segregation of small bodies of iron ore directly from it.

It is impossible here to describe all the localities where the Seboruco was observed. Sometimes, as along the Havana coast, it occupies a narrow strip extending from the point of one harbor to another. Again as on Moro peninsula opposite Havana it occurs only as a small patch in a small indentation in the old headland composed of folded Miocene rocks.

At Tanamo, and other places on the north coast the Seboruco not only forms the border of the mainland, but constitutes many islets bordering the same, with great areal extent. Generally these are low, standing only a few feet above the water.

There is a vast elongated archipelago of these elevated reefs bordering the coast all the way from a point east of Matanzas to Nuevitas. In the harbor at Nuevitas there are three islands known as Los Ballenatos which have great resemblance to the keys of the Bahamas, presenting a bold, rounded escarpment at the north point, and composed of yellow friable material,

* M. Ramon De La Sagra has defined this formation as follows: "L'autre formation de calcaire moderne, qui a recu dans le pays le nom de *seboruco*, se trouve le long de la côte, dans plusieurs endroits de l'île; elle est tellement recente, que son agglomeration continue meme aujourd'hui, et c'est a elle que l'on doit les cayes les recifs et tous les bas-fonds de coraux Les partes superieures s'elevent parfois a partir d'une profondeur de vingt a trente brasses. Toutes les inegalites de cette roche sont recouvertes d'une couche calcaire agglomerée avec des restes d'animaux. de coquilles, de coraux et de madrepores." Histoire Physique, etc. de l'Ile de Cuba, Tome I, p. 110.

which may have been either coral sand, or the yellow Miocene clays. It was impossible to get ashore or to examine them, although it was the only locality seen by me where there was a suspicion of an eolian formation. The greatest areal development of the flat Seboruco was found along the outlet to this harbor. It is found from Cape San Antonio to Cape Maycí on the north side of the island, and on the south side at many places especially at Guanabaco and Santiago, as described by Kimball.

Nowhere have I seen the elevated reef rock folded or otherwise disturbed except by the gently sloping coastward inclined elevation it has undergone. The interior margin I have never observed at a height of over forty or fifty feet. In general there is only one massive layer of this old reef rock exposed, but at Matanzas there is undoubted evidence of two older underlying reefs, the inner edges of which have been elevated with the modern reef so that they do not form distinct terraces. It may be that the almost continuous elevated reef around Cuba represents more than one of these layers. Whether one, or several alternations of reefs, the Seboruco as a whole certainly represents a recent and uniform elevation of the whole periphery of the island, at a very recent period of geologic time, but sufficiently long ago to permit of considerable alteration and erosion.

Cienegas.—Flat marshy alluvial deposits occur in many places, on the south coast. At Batabanos, opposite Havana, the coast for a mile or more inland is composed of ancient alluvial material apparently similar to a calcareous mud now depositing and forming the bottom of the adjacent sea for a mile out from land. These cienegas and cienega deposits are reported to have considerable extent at various places. The elevated portion is synchronous with the Seboruco elevation on the north coast.

A striking peculiarity, both of the older structures and the coast deposits of Cuba, is the scarcity—almost total absence—of arenaceous or sandy deposits. Nowhere is fine quartz sand found, such as accumulates around the northern border of the Gulf of Mexico, and the presence of pieces of quartz gravel in even the delta deposits is rare. This is owing to two reasons. (1) The formations of the Island—both the older metamorphic foundation and the limestones contain very little free quartz, and, (2) The littoral sands or sediments of the peripheral drainage of the Gulf are not transported as far south as Cuba, as already pointed out by Prof. Alexander Agassiz. Even the building sand of Havana and elsewhere is calcareous beach debris.

II.

Geologic History recorded by the Topography.

Having reviewed the fundamental rock structure upon which the sculpture of the land is dependent, we can now consider the general topography and its evolution. It is neither necessary nor possible to give a detailed description of the minute geography of Cuba, except so much as relates to the genesis of the island. Its shape and outlines have been described by various writers, notably Humboldt, Sagra and Reclus, and I shall only touch upon those details or generalities which will help elucidate its geologic history.

The Santiago coast is exceedingly mountainous, and is supposed in some way to be genetically connected with the mountain systems of the other Antilles. Concerning the composition, age, and topography of the mountain ranges we know but little except what has been told by other writers, to the effect that they approximately extend in an east-and-west direction, and tower far above the levels of the remaining portion of the island and occupy a very narrow strip close to the ocean's margin. Extending away to the north and west from this nucleal elevation is the main body of Cuba which is primarily a great limestone plateau deeply eroded and leveled, without any sharply defined central axis of higher elevation except the diverging headwater drainage flowing into the opposing seas. The highest elevations do not occur in a continuous ridge but are irregularly dispersed as if they were produced by the degradation of an elevated plateau resulting in the alternation of plains and irregular chains of hills, the latter often being nearer the margin than the center, and seldom over 2,000 feet in altitude.

The eminences called mountains seen by me, with the exception of the Sierra Maestra and kindred ranges of the Santiago coast, are mostly either (1) the direct remnants of the old limestone covering carved out by circumscribing erosion, or (2) inequalities in the ancient metamorphic floor from which the limestone has been denuded. The mountains of the former kind can be placed in two general classes according to their altitude and degree of erosion. First are the high limestone peaks, mesas, and ridges with a present altitude of from 1,000 to 2,000 feet. The Sierra Junki of Baracoa, the Pan de Matanzas, and the Tetas de Managua, are examples of isolated peaks, standing close to the north shore of the Island. Each of these is surrounded by deep cut drainage valleys and is many miles away from any masses of land of similar altitude. Their summits are made of the subhorizontal strata of old limestone, while the base of at least one, the Sierra Junki, con-

sists of the older metamorphic rocks. The Sierra San Juan and the high ridges of the central portion of the island are remnants of the same old level, and differ from the more isolated summits in having been less eroded. These have no regularity of arrangement or trend, but are found in irregular patches throughout the island. Their slopes are entirely the product of solution and erosion.

The Spanish language to which our geographic nomenclature is already so much indebted, has provided an appropriate name for another class of mountains. These are the Cuchillas, or "knives" so called because of the numerous sharp salients marking their slopes, and caused by the deep incision of an old plain or general level of which they are the fast fading remnant. These are the sharply serrated hills, forming the sharp background to the coasts, especially at the east end of the island. Their summits never exceed 600 feet in altitude, and are clearly the remnants of a general plain of that altitude. The Cuchillas are generally composed of the old limestone which dips at many angles and degrees, but sometimes they consist of a complexity of limestones, yellow beds, Radiolarian beds, and the old metamorphic floor. At Yumuri and around Cape Mayci, they consist of a more massive and unbroken wall of the old limestone; but as we go westward they become more eroded, as illustrated by the high line of hills along the coast and the background against which the little harbors are cut out as far west as Nuevitas. Still westward the contour recedes slightly inland. On the south of Santiago coast the same level of the Cuchillas summits are preserved in diorite and syenite.

In addition to the limestone mountains of erosion described, there are many low hills in the central part of the island adjacent to Villa Clara and Puerto Principe which are clearly structural remnants of the older metamorphic floor from which the folded limestones have been eroded, the latter often being preserved on top of the higher elevations or sharply inclined around their edges. The series of sharply rounded hills between Havana and Matanzas is also the result of the wearing away of the limestone-covering down to a floor of tuffs and serpentines, which, owing to its softer nature is more deeply and sharply sculptured than the limestone regions proper.

Although the close of the Tertiary was marked by much folding, recognizable mountains conforming to the structural folds were not seen by me.

Terraces and Benches.—The most striking feature in the topography of Cuba is the well defined terraces and benches which mark its coasts in many places. These are often so distinct, especially at the east end of the island that their con-

tinuity is traceable for many miles, as they rise abruptly from the water's level one above the other in a series of cliffs. On the west end of the island they are not so distinctly visible from any single point of view, for the flat benches are much wider, but they are nevertheless traceable. In other places denudation has destroyed them.

Besides these benches and terraces whose integrity is distinctly preserved, remnants of older and more denuded plains can be traced. For convenience they may be classified as follows:

1. The Seborneo or elevated reef plain.	1. Later terraces.
2. Elevated Beach and Cliff lines and the Havana terraces.	
3. The Cuchilla plain.	2. Older terraces.
4. The Junki plain.	

1. *The Seborneo or Elevated Reef plain.*—This forms the lowest bench immediately adjacent to the entire north coast and along the Santiago front and is topographically and geologically the elevated coral reef. Synchronous with the formation of this beach the elevated *playa* deposits in the harbors and the elevated *cienega* or mud deposit on the south side of the Island at Batabanos were made.

2. *The Beach and Cliff Terraces.*—On the east end of the island the abrupt north coast is marked by three distinct and abrupt cliffs and terraces cut out of the steep slope of the old 600 foot Cuchilla plain or which forms the upland. The three terraces as seen in this region are so clear and distinct that they are readily visible at one view and their continuity is clearly traceable for miles. They are best displayed along the coast adjacent to the mouth of the Yumuri of the east. Here the river empties directly into the sea through a precipitous cañon affording a fine cross section of the terraces. The coastal scarp consists of three narrow sub-level benches each surmounted by a vertical cliff. Bench No. 1 is the first sub-level strip above the sea, constituting the present beach. This in general represents the level of the elevated reef which nearly everywhere forms the low lying coastal plain and breaks off at the sea in a surf wall some ten feet in height. Its interior margin against the base of the first great cliff is 40 feet high, and it nowhere exceeds 100 yards in width.

This lowest, Terrace No. 1, which usually consists of elevated reef rock is composed of alluvial gravel immediately off the cut of the river, and a quarter of a mile away to the eastward it is elevated reef rock. Several smaller beaches make up this lowest terrace, the uppermost of which is the specially well defined alluvial gravel plain.

This lowest beach abuts against a vertical cliff (No. 2) about 120 feet high (170 feet above the sea) worn out of the old white limestone. Its sides are vertical in most places and inaccessible. This cliff is in turn surmounted by another beach (No. 2) which likewise was formerly an old beach level, from which has disappeared any remnant of the old deposition that may have once existed. This bench is about a hundred feet in width and abuts against a second vertical cliff, the summit of which is nearly as high as that of the first one, or about 350 feet above the sea. The level bench (No. 3) mounting this cliff is similar in appearance to No. 2.

This last bench in turn abuts against the third and uppermost escarpment of the highland, which terminates, at a height of from 500 to 600 feet, in the irregular upland plain forming the fourth level above the sea. This is the general upland as it appears from the sea, and represents the old land from which was carved the group of sea cliffs above described.

All these cliffs and benches, and the cut of the river, are carved out of the old Tertiary limestone, which here forms an unbroken mass. No trace of terraced structure occurs within the vertical walls of the river cañon, showing clearly that the stream has cut its way downward across a rapidly rising land.

The country surmounting this highest escarpment forms a comparatively unbroken plateau overlooking the sea, at the eastern end of the island, but going westward, the increasing drainage cuts it more and more into numerous serrated hills known as the Cuchillas or "Knives," whose summits, with a general culmination of from 500 to 600 feet, are clearly remnants of the Yumuri Plateau. These coastal Cuchillas are a very conspicuous feature from Nuevitas eastward.

4. *The Junki or Higher plain.*—A single glance at the peculiar isolated mountain known as the Junki or Anvil situated six miles west of Baracoa is sufficient to show that its sublevel summit is the remnant of an ancient and higher plain than that represented in the Cuchillas. This is a magnificent butte whose summit is put upon the Pilot chart and estimated by Crosby to be 1800 feet high. The summit is an ovoid mesa, looking apparently level from below, but really having deeply carved drainage ways and an ancient topography indicative of long exposure. The upper portion is composed of a mass of the older Tertiary limestones, not coral reef rock as alleged by Crosby, 1000 feet in thickness, the perimeter of which is an almost inaccessible cliff. This rests upon the old Pre-Tertiary metamorphic nucleus. From this summit one can look down upon the Cuchillas, the Yumuri terraces, the elevated reefs and the wide expanse of the ocean; and inland towards a country showing remnants of its own level, over-

reached by still higher mountains of the Sierra Maestra to the southward. On every side the drainage has cut deep below this peculiar mountain, carving the lowlying country into an intaglio of serrated hills.

No one can view this or other similar summits without being impressed with the story they tell of the great erosion which has taken place around them, as well as the fact that the difference in elevation between its plateau and that of the lower lying Cuchilla plain represents a vast hiatus in the history of the island's elevation—a long period during which land stripping and degradation ensued, reducing the surrounding areas to the old Cuchilla erosion level.

The levels represented in the three terraces of the Yumuri of the east have remarkable identity with the levels of the west end of the island, as at Havana and Matanzas, where my detailed studies were made. The only difference is that the latter are wider than the former, owing to the lower and more gently sloping country out of which they were cut. The correspondence in altitude is such that no one can doubt that they represent synchronous and identical regional movements and pauses, and that they were once continuous throughout the length of the north coasts of the island and around Cape Maysi to the Santiago coast.*

The Cuchilla, peneplain of the east, presents a resemblance to the higher summits back of Matanzas constituting the upland divide of the west end of the island in the latitude of Havana.

The oldest and highest limestone summits, about 1500 to 2000 feet in height, as typified in Junki, the Sierra del Moa, the Pan de Matanzas, the table land of Mariel, and the Managua paps of the west half of the island which follow near the north coast, the highest limestone of Santiago and other places, represent the remnant of the oldest and highest limestone levels which have been so dissected and planed down that, their extent can only be estimated. These elevations collectively may represent a higher land than existed before the Cuchilla plains were developed. Whether the high summits of the Sierra Maestra adjacent to the Santiago coast preserve traces of still older and more ancient levels is an interesting problem for the future. The interpretation of these levels cannot be finally given, without more extensive study, but the obvious history is as follows:

(1) In a period near the close of the Tertiary to be ascertained, previous to the emergence of the present elevated reef and the erosion of the Cuchilla plain, there was a great upward movement of the island to the height of at least 2000 feet,

* The levels of the Santiago region are described by Kimball in this Journal of Dec., 1884.

which as yet has revealed no history of its details, furthermore than this, that from the absence of later deposits and the character of its ancient and much sculptured topography we may fairly infer that it has not since subsided beneath the sea, but has remained mostly dry land and that its area and outline were very nearly as great as those of the island to-day. This includes those portions of the island above the dissected Cuchilla plains. (2) The Cuchillas, or 600 foot level, represent a plain which was produced by base levelling in the epoch following this oldest period of elevation and represents the time interval between it and the later movement recorded in the first or lower group. The country was planed down by erosion to near sea level; it indicates a long interval between the old Junki and the renewed modern elevation recorded in the Yumuri cliffs cut around them. (3) The Tripartite group of modern cliffs, and the base levels below and cut out of the Cuchilla escarpment, are the product of a renewed and modern upward movement which elevated the old Cuchilla base level to a plateau, and subjected it to the erosion which has since cut it into its present rugged outlines. The Yumuri cliffs were carved from it where it formed a sharp coast scarp, and the Havana and Matanzas benches represent synchronous levels with the latter in the west end of the island where the Cuchilla plain was of less extent. This modern group of elevations was intermittent as is shown by its alternate cliffs and terraces. The modern Seboruco represents the latest and newest regional uplift.

The elevated benches and terraces which border the coast of Cuba with the single exception of the Seboruco or modern coast reef, are not ancient coral reefs either topographically or lithologically, as has been asserted; on the other hand they are beach and erosion plains, produced during a rapid elevation of the island in Post-Tertiary time and carved from various formations principally the older limestones, regardless of structural arrangement and composition. Even if the old limestones are coral-made these old terraces can in nowise be interpreted topographically as elevated reefs, for none of the original reef topography is preserved. On the other hand I can give numerous instances where the same levels are carved out of varying component material which was much folded or disturbed prior to their erosion.

The series of terraces around Cape Mayci and Yumuri are carved out of a massive matrix of old limestone of undulating structure. The terraces at Matanzas are cut out of a series of beds of widely divergent lithologic composition, and all dip at angles from ten to twenty-five degrees. The Moro and Principe Plateau at Havana is a planation surface upon a floor of

folded limestone, in which a distinct anticlinal structure can be traced. The terrace upon which the Military Hospital at Baracoa is situated is carved across the almost vertically inclined edges of the older Miocene limestones. The summit of Junki instead of being coral reef is a greatly degraded peneplane. The Seboruco alone of all the levels is topographically an elevated reef and this, as before stated, does not rise anywhere over 50 feet above the sea.

Lack of Evidence of Subsidence.—The writer was unable to discover positive evidences of subsidence after the beginning of Tertiary time, or accompanying these elevations, although it would be rational to think that the movements must have been oscillatory. I failed to find any traces in the upland areas of recent deposits which would indicate any extensive submergence. The soils are everywhere residual, and nowhere did I observe any that could be attributed to transported material or overplacement of marine sediment, and particular care was taken to look for such evidence. Castro reports extensive upland alluvial deposits in the region of Puerto Principe, but gives no evidence whereby we may determine whether they were produced by upland lacustral deposition or submergence of the land to sea level. Nowhere do the rivers show any revival or other evidence of such subsidence, but all have continuous downward cutting sections.

Whether there has been recent subsidence immediately preceding the deposition of the elevated coral reef or Seboruco, whereby the circular harbors were produced as Crosby alleges, is also a point which I cannot accept, though difficult to determine. He advances in support of his position the structure of the circular harbors and the great thickness of the older limestones which he believed to be ancient reef rock. I have endeavored to show that there is no evidence to support the theory that the older elevated limestones were coral reefs in origin, and hence it is not necessary to here discuss this testimony further.

Concerning the mouths of the rivers themselves, their alluvial deposits and the evidence of their valleys may be interpreted to mean elevation more positively than Mr. Crosby interprets them to mean subsidence, nor can I understand why he calls them "half drowned." There is a singular absence of fiord-like valleys or indentations or of ancient estuarine deposits around the coast of Cuba, such as ordinarily indicate subsidence. In fact the rivers in nearly all cases, like the Yumuri of the east, run directly to sea level through almost vertical chasms cut directly across the line of terraces, and are void of any terraces within their cañons, showing unmistakably that they have cut down to sea level across the terraces.

That some of these rivers do at present reach tide level a short distance from the beach is true, but so short is this distance that vessels can always obtain fresh water from them by sending light boats up them less than a mile from where they enter the seas or harbors. I do not think that this slight indentation of tide level up these rivers is indicative of "drowning" or an ancient subsidence; on the contrary, it merely means that the rivers and surf are doing their normal work of degrading the land. If there were really drowned rivers they would be navigable some distance inland, but in case of the three largest streams, the Armendaris of Havana and the two Yumuris of Matanzas and Baracoa I found it impossible to go inland over a mile in the shallowest row boat, being soon retarded by rapids.

On the other hand some of these streams are now forming delta deposits in places outside their mouths, which is more indicative of present elevation than of subsidence. Furthermore, the Yumuri of the east formed similar deltas before the elevation of the coast reef. At any rate, if there had been any serious epochs of subsidence, they would be recorded in great fiord-like valleys or low passages across the central axis of the Island, such as do not exist, and to which the oval harbors may not be compared, for their origin is entirely due to the pre-existing fringe reefs.

On the other hand, it might be alleged that all the ancient topography of subsidence is still beneath the ocean level, and that the angular edges of Cuba are indicative of the fact that the present outline merely represents an ancient summit which is re-emerging. The submarine topography, however, is not within the province of this paper, but I agree with Prof. Agassiz that its irregularities were indicated long before the present history treated, in this paper. The three alternations of gravel and reef in the Matanzas section may also have indicated slight alternations of subsidence and elevation.

It is now possible with the aid of the stratigraphic and paleontologic data previously given to make a few conclusions concerning the Cenozoic history of Cuba. It has been shown by the stratigraphy that the topographic levels are not old reef levels but with the exception of the modern reef, have all been carved out of the previously folded and disturbed Tertiary limestones, and hence the present bench topography of Cuba originated subsequently to this period of Post-Tertiary wrinkling and represents a different kind of movement which was regional or epeirogenic. Since the old folding or orogenic movements occupied at least a small portion of Post-Tertiary time, we may reasonably conclude that the periods of uniform

uplifting recorded in the old levels must have taken place at least since the beginning of the Pleistocene. In other words they are comparatively modern in geologic time—some of them absolutely recent.

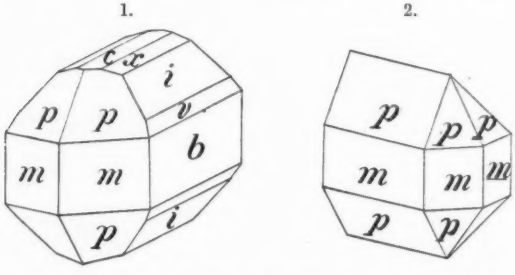
It is not maintained in this paper that these epochs of regional elevation were continuous and uninterrupted, or unaccompanied by pauses or even alternating epochs of subsidence, but the general progress of the island has been periodically upward and if there were epochs of subsidence they are difficult to distinguish and were of short duration and insignificant in comparison with the great uplifting movement that has generally progressed.

ART. XXIX.—*Mineralogical Notes on Cerussite, Calamine and Zircon;* by J. H. PRATT.

1. *Cerussite.* — The mineral occurs at the Judge Mine, Black Hawk, Meagher Co., Montana, and was collected, through the kindness of Mr. Davis, foreman of the mine, by Mr. L. V. Pirsson, during the summer of 1893 while engaged in field work on the U. S. Geological Survey.

It is associated with several ores of lead resulting from the decomposition of galena, the main constituent of the ore body. The mineral is found in pockets in the form of rough masses, at times as large as one's fist, showing an occasional broad crystal face. These fragments are remarkably clear and free from foreign inclusions. Attached to these are small bright crystals, both simple and twinned. Their faces are generally smooth, giving very good reflections of the signal when measured on the reflecting goniometer.

Specimens of the simple crystals which are represented by fig. 1, were found so attached to the rest of the mineral that



the faces on both ends of the lateral axes were developed and could be measured. The forms observed on them are:

b (010, i-$\breve{\imath}$)	*x* (012, $\frac{1}{2}$-$\breve{\imath}$)	*v* (031, 3-$\breve{\imath}$)
c (001, *O*)	*i* (021, 2-$\breve{\imath}$)	*p* (111, 1)
m (110, *I*)		

The greater part of the crystals observed however were twinned; the twinning following the common method in which the twinning plane is the unit prism *m*, *I*, 110. These crystals are represented by fig. 2. As shown in the figure, the crystals are extended in the direction of the twinning plane and are so attached against the smooth surfaces of larger crystal faces that the twinned pinacoids at the other end are wholly wanting, the crystals being cut square off at this point as in the figure. They resemble strongly the untwinned ones.

The following table shows the identification of the forms by calculated and measured angles. For obtaining the calculated angles the elements of Koksharov* have been used in which,

$$\breve{a} : \bar{b} : \breve{c} = 0{\cdot}609968 : 1 : 0{\cdot}723002.$$

	Calculated.	Measured.
$m \wedge m$, $110 \wedge 1\bar{1}0$	62° 45′ 50″	62° 45′, 62° 45′, 62° 45½′
$m \wedge p$, $110 \wedge 111$	35 46	35 46, 35 45, 35 46½
$p \wedge p$, $111 \wedge 1\bar{1}1$	49 59 30	49 58, 49 57½
$c \wedge x$, $001 \wedge 012$	19 52 30	19 49, 19 51
$c \wedge i$, $001 \wedge 021$	55 20	55 19, 55 19
$c \wedge v$, $001 \wedge 031$	65 15	65 9, 65 11
$m \wedge m$, $110 \wedge 110$ (twin)	54 28 30	54 28, 54 29, 54 26
$m \wedge p$, $110 \wedge 111$ "	43 36 30	43 39½

2. *Calamine.*—So far as the author has been able to discover no calamine from any American locality has been described with respect to crystal habit and it has been thought that a brief description of crystals from some of the occurrences, with figures, would be of interest and not without value.

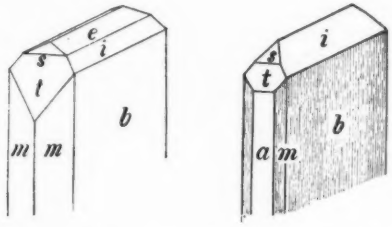
Specimens of this mineral from the majority of American localities rarely show distinct isolated crystals, but rather, masses of them agglomerated together upon the brachy pinacoid, into rounded forms similar to prehnite and these pass into indistinct botryoidal and even earthy amorphous crusts.

In the fine suite of specimens in the Brush collection were found some from Sterling Hill, New Jersey, and from the Harriet and Maid of Erin Mine, Clear Creek Co., Colorado, which contained separate distinct crystals suitable for measurement on the reflecting goniometer. They all show the same habit being thin tabular on *b*(010) and also extended so greatly in the direction of the vertical axis as to form long slender, delicate, needle-like forms.

* As given in Dana's Mineralogy, sixth edition, 1892, page 286.

The crystals from the first mentioned locality are terminated by brachy- and macro-domes as represented in fig. 3. No doubly terminated ones were observed, all being attached upon the pyramidal or antilogous end. The prism faces are more or less striated but not so greatly but that sufficiently accurate measurements could be obtained to identify them. The domes

3. 4.



were bright and smooth and gave very good reflections of the signal. The faces observed on these crystals are as follows:

b (010, i-$\breve{\imath}$)	*s* (101, 1-$\bar{1}$)	*e* (011, 1-$\breve{\imath}$)
m (110, *I*)	*t* (301, 3-$\bar{1}$)	*i* (031, 3-$\breve{\imath}$)

The crystals from Clear Creek Co., Colorado, as shown by specimens in the Brush collection occur in cavities in hematite. They are similar to those from Sterling Hill but have in addition the macro-pinacoid *a* (100, i-$\bar{\imath}$), while *e* (011, 1-$\breve{\imath}$) is wanting. These crystals which are represented by fig. 4 are so greatly striated that no measurements could be made in the prism zone.

The following table gives the calculated and measured angles. For obtaining the calculated ones the elements of Schrauf* have been used in which

$$\breve{a} : \bar{b} : \dot{c} = 0{\cdot}78340 : 1 : 0{\cdot}47782.$$

	Calculated.	Measured,
$a \wedge s$, $100 \wedge 101$	58° 37′	58° 40′, 58° 40′
$a \wedge t$, $100 \wedge 301$	28 39 30″	28 38 30″, 28° 35′
$b \wedge i$, $010 \wedge 031$	34 54	34 51
$i \wedge i$, $031 \wedge 0\bar{3}1$	110 12	110 11 30
$e \wedge e$, $011 \wedge 0\bar{1}1$	51 5	51 11
$m \wedge m$, $110 \wedge 1\bar{1}0$	76 9	76 36

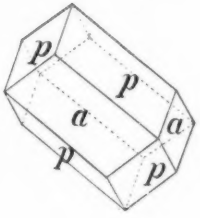
Zircon.—In a recent paper Prof. F. D. Adams† has described the occurrence of a large area of nephelite syenite from the townships of Dungannon and Faraday, Ontario, and

* Dana's Mineralogy, sixth edition, page 546.
† This Journal, vol. xliii, p. 10, 1894.

mentions zircon as one of the rock constituents. Some specimens of these zircon crystals have been sent to this laboratory recently by Prof. Adams for crystallographic investigation and as they present several points of interest a brief description of them is given here.

The crystals occur imbedded in the usual manner in the rock, from which they can readily be separated in a nearly perfect condition. They show two quite different habits, one, represented in fig. 5 in which by the development of two opposite pairs of the pyramidal faces together with a pair of the prisms of the second order, the crystal becomes columnar

5.



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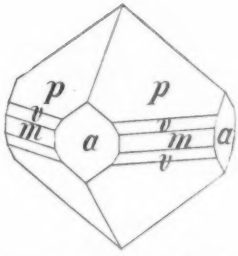


in this direction and mimics a hexagonal prism of the second order terminated by rhombohedral faces. The only forms observed on these are:

a, *i-i*, (100); and *p*, 1, (111).

In the second habit the pyramidal faces are strongly developed, while the prism faces are short or lacking altogether. These crystals represented by fig. 6, show the following forms.

a, *i-i*, (100); *m*, I, (110); *v*, 2, (221); *p*, 1, (111).

The crystals are well suited for measurement and give fair reflections of the signal on the goniometer. In the following table of calculated and measured angles, the elements of Kupffer* were used to obtain the calculated angles, where,

Axis $c' = 0{\cdot}640373$.

		Calculated.	Measured.
$m \wedge p$,	$110 \wedge 111$	47° 50′	47° 42′ 30″
$m \wedge v$,	$110 \wedge 221$	28 54	28 52
$a \wedge p$,	$100 \wedge 111$	61 40	61 38
$p \wedge p'$,	$111 \wedge \bar{1}11$	56 40 26″	56 38
$p \wedge p''$,	$111 \wedge \bar{1}\bar{1}1$	84 20	84 16

In conclusion the author desires to express his thanks to Mr. L. V. Pirsson for valuable aid during the progress of the work.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, June, 1894.

* Dana's Mineralogy, sixth edition, p. 482.

ART. XXX.—*The Reduction of Arsenic Acid by the Action of Hydrochloric Acid and Potassium Bromide;* by F. A. GOOCH and I. K. PHELPS.

[Contributions from the Kent Chemical Laboratory of Yale College—XXXIV.]

IT was shown in a a former paper from this laboratory* that arsenic acid may be easily reduced by the simultaneous action of hydrochloric acid and potassium iodide, and more recently † this reaction has been successfully applied to the rapid detection of arsenic in presence of antimony and tin, and of antimony and tin associated with arsenic. This paper is the account of work in the course of which it became evident that the action of hydrobromic acid upon arsenic acid is so similar to that of hydriodic acid that potassium bromide may with propriety, and even with advantage, be substituted for the iodide in the process of reduction.

The apparatus which we have used in this work is similar to that employed previously, and is essentially a Mohr's distillation apparatus—consisting of a small flask, of from 25cm³ to 50cm³ capacity, fitted by means of a pure rubber stopper to a pipette which was bent, drawn out at the lower end, and dipped into a test-tube supported and cooled in an Erlenmeyer flask nearly filled with water. The arsenic was introduced into the flask in the form of the pure crystallized dihydrogen potassium arseniate which was dissolved with 3grm of potassium bromide in 5cm³ of water, and 5cm³ of hydrochloric acid of full strength (sp. gr. 1·20) were added. The end of the pipette tube was dipped into 5cm³ of hydrochloric acid of half strength contained in this test tube used as a receiver, and the distillation was carried on until the liquid in the flask had almost entirely passed to the receiver. The residue was treated with 10cm³ of the strongest hydrochloric acid, and the distillation was repeated with the modification that this time the condensation was effected by passing the volatile material into 10cm³ of water, so that the liquid in the receiver at the end of this operation should have the acidity of hydrochloric acid of half strength. This process of treating the residue with the strongest hydrochloric acid and distilling was continued until arsenic ceased to be discoverable in this distillate. At the beginning of the distillation bromine is liberated and collects in this distillate; but later, as the arsenious chloride volatilizes and condenses again, the color of the bromine in the distillate vanishes with

* Gooch and Danner, this Journal, xliv, 308.
† Gooch and Hodge, this Journal, xlvii, 382.

the simultaneous reconversion of the arsenic to the higher form of oxidation. In such a solution, especially if it is not very hot, hydrogen sulphide precipitates the arsenic only slowly, but the addition of a little stannous chloride dissolved in hydrochloric acid of half-strength to the hot solution reduces the arsenic to the lower form of oxidation and prepares the way for the immediate precipitation of arsenious sulphide by hydrogen sulphide. Antimonic acid is likewise reduced under the conditions of the distillation; but, as Koehler has shown,* neither small amounts of antimony and tin, which if present originally may pass partially to the distillate, nor the tin added to effect the reduction of the arsenic finally, will be precipitated by hydrogen sulphide under the existing conditions of temperature and acidity.

The results of experiment are recorded in the accompanying table.

	Arsenic taken as H_3AsO_4 grm.	Antimony taken as H_3SbO_4 grm.	Tin taken as $SnCl_4$ grm.	Precipitation by H_2S in successive distillates after treatment with $SnCl_2$	Precipitation by H_2S in the residue dissolved in water.
(1)	----	----	----	I None	None
(2)	----	----	----	I–X None	Faint coloration
(3)	0·0001	----	----	I Found II None	None
(4)	0·0010	----	----	I Found II None	None
(5)	0·0100	----	----	I–II Found III None	None
(6)	0·1000	----	----	I–III Found IV None	Faint coloration
(7)	0·4000	----	----	I–VI Found VII None	Orange precipitation†
(8)	1·0000	----	----	I–X Found XI None	Orange precipitation†
(9)	----	0·4000	----	I None	Large
(10)	0·0001	0·4000	----	I–II Found III None	Large
(11)	0·0001	0·0001	----	I Found II None	Distinct color
(12)	0·0010	0·0001	----	I Found II None	Distinct color
(13)	0·0100	0·0001	----	I–II Found III None	Distinct orange
(14)	----	----	0·4000	I None	Large
(15)	0·0001	----	0·4000	I–II Found III None	Large
(16)	0·0001	----	0·0001	I Found II None	Distinct color

* Zeit. für Anal. Chem., xxix, 192.

† Subsequently identified as antimony sulphide by depositing the metal on platinum.

Whenever antimony was introduced intentionally it was taken in the form of antimonic acid produced by oxidizing by bromine in alkaline solution tartar emetic purified by boiling with hydrochloric acid until the distillate contained no trace of arsenic. The stannic chloride employed was similarly purified by boiling in strong hydrochloric acid.

It will be seen that no indication was given by hydrogen sulphide either in the distillate or residue when the hydrochloric acid ($10cm^3$) and the potassium bromide (3^{grm}) were treated in blank. When the bromide was treated in blank ten times successively no indication was obtained in any individual distillate, but the residue showed a trace of color which was apparently intensified by the action of hydrogen sulphide. This effect was slight and probably due to the prolonged action of the acid upon the rubber. It is not sufficient to interfere with the detection of 0.0001^{grm} of antimony—as subsequent experiments showed.

A single distillation, requiring but three or four minutes, proved to be sufficient for the complete volatilization of 0.0010^{grm} of arsenic, two distillations were enough to remove 0.01^{grm}, and three 0.1^{grm} of arsenic. In handling larger amounts of arsenic, 0.4^{grm} or $1.^{grm}$, it became evident that the presumably pure arseniate actually contained a trace of antimony, and the efficiency of the bromide treatment in effecting the detection of a little antimony in presence of a large amount of arsenic is clearly shown. It is plain that while the presence of large amounts of antimony and tin tend to diminish the rapidity of volatilization of the arsenic, the detection of 0.0001^{grm} of arsenic is always sure, and that antimony and tin if originally present in appreciable amount will always be discoverable in the residue.

In a comparison of the results of these experiments with those recorded in the former paper describing the reduction by means of potassium iodide, it appears that in general fewer distillations are needed to effect the transfer of the arsenic to the distillate when the bromide is employed—a condition of affairs which is doubtless due to the fact that in the former treatment an insoluble and somewhat refractory precipitate of arsenious iodide is formed when large amounts of arsenic are present, while the bromide causes no precipitation of the arsenic, and interferes in no way with the distillation of the reduced product.

ART. XXXI.—*On the Occurrence of Leadhillite in Missouri and its Chemical Composition;* by L. V. PIRSSON and H. L. WELLS.

LEADHILLITE, the hydrated sulphato-carbonate of lead, is a rare mineral, occurring in but a few places in Europe and having been reported from but three localities in this country.*

It is therefore a matter of interest to announce a new occurrence in America, and as the exact chemical composition of the mineral has been uncertain and the material is well suited for mineralogical and especially for chemical investigation, these have been undertaken with the results given in the present article.

Our attention was first called to this occurrence by Messrs. English and Co., of New York City, who sent us some specimens for identification and we take great pleasure in expressing our thanks to these gentlemen for the very liberal manner in which they have placed an abundant supply of fine material at our disposal for this investigation.

The mineral occurs near Granby, Missouri, and has been probably formed by the action of water, carrying carbonic acid and oxygen in solution, on galena.

The specimens which we have studied consist of masses and crusts often apparently pseudomorphous after the original lead ore and consisting mainly of massive cerussite, mingled possibly with other lead salts. The leadhillite occurs implanted upon this in well defined crystals or in aggregated groups studding the interior of cavernous portions of the amorphous crusts.

The isolated crystals are often quite perfect, in rather slender, apparently hexagonal prisms attaining a length of 50^{mm} and terminated at either end by the basal plane. More commonly, however, they occur in rather thick hexagonal tables, at times 1^{cm} in breadth, numbers of which are grouped together in parallel position or consisting of repeated twins. When these occur lining cavities only the front half of the crystals are often developed, and as they extend to right or left or rise one above the other, all in parallel position, they represent in miniature precisely the appearance shown by columnar cliffs of basalt whose broken off hexagonal columns rise step-like above each other.

In these cavities they are often associated with slender, striated, glittering prisms of cerussite, occurring at times in fine twins, the twinning plane being the prism r (130).

* Newberry Dist.; Spartanburg Dist., No. Car. by Shepard and from the Schultz gold mine in Arizona, by Penfield, cf. Dana's Min. 6th ed., p. 922, 1892.

In color the leadhillite varies from colorless in the smaller crystals which are often beautifully clear and limpid, to an exquisite clear sea-green in the larger translucent individuals.

From their freshness, high luster, delicate tints, size and good crystallization these specimens are by far the most striking ones of this mineral that have come under our observation.

Crystallography.—From a crystallographic standpoint the mineral from this new locality is very simply developed, the majority of the crystals appearing like simple hexagonal prisms terminated by the base and consisting of the forms *c*, *o*, (001); *m*, *I*, (110) and *a*, $i\text{-}\bar{i}$ (100). Often the positive hemidome *e*, $2\text{-}\bar{\imath}$, ($\bar{2}01$) is present and the crystals have the habit shown in fig. 1. More rarely the negative hemidome *u*, $-2\text{-}\bar{\imath}$ (201), and the ortho-pyramids *q*, $1\text{-}\bar{4}$, ($\bar{4}14$) and *μ*, $\frac{1}{2}\text{-}\bar{4}$($\bar{4}18$) occur and these are shown in fig. 2, which represents the most

Fig. 1.

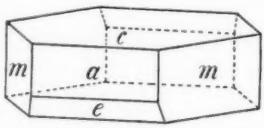
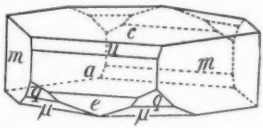


Fig. 2.



complex form observed. These have been identified by the following angles measured on the reflecting goniometer. For the calculated angles the elements derived from the measurements of Laspeyres* have been used in which

$$\dot{a} : \bar{b} : \dot{c} : : 1{\cdot}74764 : : 1 : 2{\cdot}21545, \text{ ang. } \beta = 89^\circ\ 47'\ 38''.$$

	Calc.	Meas.
$c \wedge a$ (001 ∧ 100)	89° 47′ 38″	89° 38′, 89° 37′ = ang. β.
$m \wedge m$(110 ∧ 1$\bar{1}$0)	120 27	120 22
$c \wedge m$(001 ∧ 110)	89 54	89 39
$c \wedge e$ (001 ∧ $\bar{2}$01)	68 39	68 54 69 04
$c \wedge u$ (001 ∧ 201)	68 18	68 27
$c \wedge q$ (001 ∧ $\bar{4}$14)	54 16	54 14
$c \wedge \mu$ (001 ∧ $\bar{4}$18)	34 09	34 37

The above measurements represent the best obtained; as a general rule the reflections of the signal are poor in spite of the brilliancy of the luster, owing to the fact that the crystals are usually much striated by lines parallel to the trace of the basal plane and are moreover often slightly curved or twisted. The measurement of $c \wedge a$ (001 ∧ 100)=ang. β was one of the best and obtained on a small crystal which gave good reflections and was free from distortion; it is somewhat less than

* Zeit. f. Kryst., i, p. 199, 1877.

that given by Laspeyres and approaches the angle measured by Artini* on the Sardinian mineral, ang. $\beta = 89° 31' 55''$. The plane μ, $\frac{1}{2}\bar{1}$, $(\bar{4}18)$ first mentioned by Artini, is easily identified in the present occurrence by its lying in the zone $\bar{4}10 \wedge 001$ and by the measurement on the base. It may be mentioned here that all the faces shown in fig. 2 have been greatly exaggerated except the pinacoids and prisms, in order to exhibit them better.

One of the most marked peculiarities of leadhillite is its close approach to hexagonal symmetry in certain of its forms. Thus we have,

$a \wedge m$	$100 \wedge 110 = 60°$	$13' 30''$
$c \wedge u$	$001 \wedge 201 = 68$	18
$c \wedge e$	$001 \wedge \bar{2}01 = 68$	39
$c \wedge x$	$001 \wedge 111 = 68$	31
$c \wedge r$	$001 \wedge \bar{1}11 = 68$	42

A combination of these planes evidently could not be distinguished by the eye alone from a hexagonal prism terminated by a hexagonal pyramid. The crystals from Missouri often appear strongly rhombohedral from the fact that they have the habit shown in fig. 1, and are repeatedly twinned on the unit prism. Where the edge between the base and a face in the prism zone is replaced by a single plane as in fig. 1, and the reflections are poor it is often impossible to locate this plane and orient the crystals.

The examination of a cleavage plate in convergent polarized light gives the trace of the axial plane, however, and enables one to decide at once between the pyramids and hemidomes given in the above table, but since the inclination of the angle β is so slight it is still impossible to tell whether they are in the obtuse or acute angle. In the present case the orientation adopted is that given by the agreement between the best measurements and the calculated angles and as these are very close it is regarded as undoubtedly correct.

Twinning.—As previously mentioned twinning on the unit prism is very common. Cleavage plates in polarized light are also seen to contain lamellæ twinned in this way.

Cleavages by reflected light rarely present a perfectly plane surface, but are covered with slight re-entrant and salient angles in all directions, which reflect, on the goniometer, numerous scattered images of the signal.

If the mineral was orthorhombic it is evident that the bases of the intergrown twinned, individuals would all lie in one plane, but as it is really monoclinic these small, apparently vicinal angles are due to the slight inclination of $a(100) \wedge c(001)$.

* Giorn. Min., i, 1, 1890.

They are not sufficiently large, however, to prevent a simultaneous production of cleavage over the twinned individuals as a whole.

In some cases it appears as if the composition face in twinning was the base (001). Certain cleavage plates examined in convergent light display two axial images superimposed upon each other, the lines joining the focal points of the lemniscate figures being at angles of 60°. Such a method of twinning is like that of the micas and chlorites which indeed leadhillite with its pronounced basal cleavage and simulation of hexagonal symmetry resembles.

To this may be due as suggested by Groth* the optical character of the doubtful mineral susannite which was determined to be uniaxial by Bertrand† on material from Matlock and which we have confirmed by examination of a cleavage plate from a single specimen from Leadhills in the Brush collection.

Physical properties.—The *cleavage* parallel to the base is very perfect and easily produced. The *luster* of the natural basal plane is pearly, while that of cleavage plates is sometimes pearly and sometimes adamantine like that of the faces in the prismatic zone. The luster of the ortho-pyramids is often dull or lacking, resulting from innumerable microscopic pittings. The *hardness* is nearly 3. The *specific gravity* is 6·54, which agrees almost exactly with Hintze's‡ determination, 6·547, for the Sardinian mineral. Our determination was made on a chemical balance at 25° C. with a pure solid fragment weighing over 2 grm. The precaution was taken to remove air before weighing in water, by placing the fragment under water in a vacuum. To use boiling water at 100° for this purpose is inadmissible, because when the mineral is heated in water to this temperature, it becomes filled with a multitude of cracks and afterwards falls to powder upon the application of a slight pressure.

Optical properties.—Cleavage plates being clear and colorless furnish excellent material for optical investigation. The axial plane is, as in all known occurrences, parallel to a (100) and the acute bisectrix practically perpendicular to c (001). The optical character is negative. The angle of the optic axes is small and the dispersion sensibly large, $\rho < \upsilon$. This was confirmed by measurement of a plate with the large Fuess axial angle apparatus at 25° C. with these results.

$$2E_{Tl} = 20°\ 27'$$
$$2E_{Na} = 20\ \ 08$$
$$2E_{Li} = 18\ \ 52$$

* Tabel. Uebesicht. Min., 1889, p. 62.
† Compt. Rend., lxxxvi, p. 348, 1876.
‡ Pogg. Ann., clii, p. 256.

This agrees pretty closely with the observations of Descloizeaux* and of the other investigators mentioned in this article. Bertrand† gives 2 $E_y = 72°$ for the mineral from Matlock, and as it exhibited other optical anomalies mentioned by him the occurrence appears to need confirmation by chemical analysis.

As usual the optic angle diminishes rapidly with increase of temperature. Plates placed on the heating attachment for the microscopic of Fuess became uniaxial when the thermometer registered about 100°C.; the plates themselves, being exposed to the air, were at a somewhat lower temperature. During the process the turning lamellæ disappear as noted by Hintze‡ and Mugge§ and the plate becomes uniform in polarization. In the course of a day or so the uniaxial character disappears and the normal one is resumed. This change seems to be due to molecular rearrangement as the mineral does not suffer any chemical change, as shown by the careful experiments of Hintze.‖

Etching figures.—The monosymmetric character of leadhillite is well shown by the form and disposition of the etching figures produced on the basal surface of cleavage plates by very dilute nitric acid.

After the action of the acid has continued a few moments and the surface has been rinsed and cleaned with water, it is found to be covered with delicate markings. With high powers of the microscope these are resolved into shallow pits whose outline on the surface is the projection of a nearly equilateral spherical triangle.

One side of the triangle is tangential at its middle point to the trace of the orthopinacoid (100) on the base (001) while the opposite angle is bisected by the symmetry plane. The sides of these depressions curve towards each other as they descend and either end in a dihedral angle or in a small plane which truncates it.

Thus the character of the figures produced by etching is precisely similar to that of the micas described and figured by Baumhauer¶ and shows the monoclinic symmetry in the same way.

When the action of the acid is more rapid, the etchings run into one another and in this way the twinned character of cleavage plates, the arrangement of the twinned bands and different individuals is quite clearly brought out.

Chemical composition.—Although leadhillite has been frequently analyzed, its chemical composition has remained some-

* Propr. Opt., 2, 38 N. R. 72, 1867.
† Loc. cit.
‡ Pogg Ann, clii, p. 259, 1874.
§ Jahr. f. Min., i, pp. 63, 204, 1884.
‖ Pogg. Ann., clii, p. 256.
¶ Zeit. für Kryst., vol. iii, p. 113, fig. 12, 1879.

what doubtful. The earlier investigators, including such eminent chemists as Berzlius and Stromeyer, failed to take into account the small amount of water in the mineral, so that its composition was incorrectly supposed to be represented by the formula, $PbSO_4 . 3PbCO_3$.

Laspeyres, in 1872, described "maxite" as a new mineral, which, while resembling leadhillite in other respects, was hydrous. The question of the identity of maxite and leadhillite was for some time the subject of a considerable amount of controversy,* but it was satisfactorily shown by Hintze† that leadhillite was also hydrous and that there was therefore no ground for considering maxite as a separate species, and this was finally admitted by Laspeyres.‡

The formula given to maxite by Laspeyres was, $18PbO . 9CO_2 . 5SO_3 . 5H_2O$. Hintze's formula for leadhillite as well as maxite was, $7PbO . 4CO_2 . 2SO_3 . 2H_2O$. A simpler and more rational formula has been recently suggested by Groth,§ $4PbO . 2CO_2 . SO_3 . H_2O$. The calculated compositions and the molecular ratios for the three formulas are as follows:

	Laspeyres. $18PbO . 9CO_2 . 5SO_3 . 5H_2O$.	Hintze. $7PbO . 4CO_2 . 2SO_3 . 2H_2O$.	Groth. $4PbO . 2CO_2 . SO_3 . H_2O$.
H_2O	1·84	1·86	1·69
SO_3	8·16	8·27	7·53
CO_2	8·08	9·11	8·29
PbO	81·92	80·76	82·49

	PbO :	CO_2 :	SO_3 :	H_2O.
Laspeyres,	$3\frac{3}{5}$	$1\frac{4}{5}$	1	1
Hintze,	$3\frac{1}{2}$	2	1	1
Groth,	4	2	1	1

A comparison of the above shows that the differences are not large, and it is evident that slightly impure material or small analytical errors would account for the variations from Groth's simple formula. It is to be noticed also that the determinations of SO_3, made in leadhillite before it was known to be hydrous, agree much more closely with Groth's formula than with the other two. A list of these as cited by Hintze is as follows:

	SO_3
Berzelius	7·58
Stromeyer	7·21
Thomson	7·24
Irving	7·66
Bertrand	7·14

* Laspeyres, Jb. Min., 1872, 407, 508; 1873, 292; J. pr. Ch., N. F., v. 470; vii, 127; xiii, 370; Bertrand, Bull. Soc. Chim., xix, 17; C. R. lxxxvi, 348; Hintze, Pogg. Ann., clii, 256.

† Loc. cit. ‡ Zeitschr. Kryst., 1877, 193.

§ Tabell. Uebersicht. Min., 1889, p. 62.

It will be shown beyond that Groth's formula is the correct one, and it is evident that the earlier analysts would have arrived at it if they had detected and determined the water.

Chemical Analysis.—Some of the methods that have been previously used for the analysis of leadhillite have been rather severely criticized, and the operation has been characterized as attended with difficulties. It seems necessary, therefore, to give the process used in the present investigation with some detail.

The carefully selected material was pulverized, and about 2^g of the substance, without any artificial drying, was weighed in a platinum boat. The boat was placed in a dry piece of combustion tubing, to one end of which the ordinary apparatus for weighing water and carbonic acid was attached. A slow stream of pure, dry air was passed through the tube and apparatus, and the substance was heated to low redness until the water and carbonic acid were driven off and absorbed in the weighed apparatus. The sum of the weights of the water and carbonic acid varied but 0·07 per cent from the loss in weight of the substance. The water in the calcium chloride tube was neutral to litmus paper, thus showing that no SO_3 had been driven off. In fact a much higher temperature than that used will not decompose lead sulphate if reducing gases are absent.*

The ignited substance was transferred to a platinum crucible and fused with three or four parts of sodium and potassium carbonates to which a trace of potassium nitrate was added. The mass was treated with 2 or 300^{cc} of hot water to which a little ammonium carbonate was finally added. After cooling, the residue was filtered off and washed. Preliminary experiments had shown that the filtrate from this contained scarcely a trace of lead, and it was therefore used for the determination of sulphuric acid, as barium sulphate, in the usual way.

The insoluble residue, consisting of lead oxide with some carbonate, was dissolved in dilute nitric acid. The solution was complete except that a trace of lead peroxide remained which was dissolved in a little hydrochloric acid. The solution containing all the lead was evaporated with sulphuric acid, and after taking up the residue with water, the lead sulphate was collected in a Gooch crucible, ignited to low redness with careful protection from the action of reducing gases and weighed. Nothing could be found in the filtrate from the lead sulphate except extremely minute traces, probably of lead and iron.

* Fresenius states that lead sulphate does not lose weight at the most intense redness. (Quant. Anal, Analyt. Expt. No. 52.)

The material used for the analysis was from a single large crystal and it appeared to be perfectly pure. It had a pale green color and moderately thick pieces were transparent. The results of the analysis are as follows:

	Found.	Ratio.	Calculated for $4PbO \cdot 2CO_2 \cdot SO_3 \cdot H_2O$.
SO_3	7·33	1	7·53
CO_2	8·14	2·02	8·29
PbO	82·44	4·04	82.49
H_2O	1·68	1·02	1·69
	99·59		100·00

These results show that the mineral has the formula $PbSO_4 \cdot 2PbCO_3 \cdot Pb(OH)_2$ and corresponds to the composition suggested by Groth, thus adding one more to the many cases in which his remarkable acuteness has deduced a simplified and correct formula from the more complicated results of previous investigations.

Sheffield Scientific School, New Haven, Conn., June, 1894.

Art. XXXII.—*Thermo-Electric Heights of Antimony and Bismuth Alloys;* by C. C. Hutchins.

The writer, being much interested in the preparation and use of thermo-couples of very small mass, undertook the following experiments with a view to finding the best combination of elements for the purpose.

Much study has been devoted to the subject already, chiefly however for the production of thermopiles designed to replace ordinary batteries. The extremely brittle alloys or sulphides used in these exclude them from the list of available elements when the elements are to be made very thin and are to have several soldered joints.

We have numerous determinations of the electromotive force of thermo-couples by Matthiessen and others, but it is impossible to repeat their experiments, owing to the want of method in the preparation of the couples, and the effects of impurities in the metals used by them.

The effect of physical state of the metal upon its thermo-electric height is clearly seen in Jenkins' table, compiled from Matthiesen's experiments. Here the thermo-electric height of antimony pressed wire is 280 C. G. S. units; but for the same metal with the equator of a crystal 2640. We are not assured

however that the wire and crystal were from the same sample of metal.

The effect of impurities can be seen in the table for bismuth and tin given below, where it is seen that the presence of a third of one per cent of tin is sufficient to reverse the direction of the electromotive force of bismuth. Plainly then, if we expect to arrive at anything more than the general order of magnitude of the quantities involved, the greatest care must be taken to procure materials in a state of purity, and from these materials the elements must be prepared in a uniform manner.

Apparatus.

A copper bar, $1{\cdot}5^{cm}$ square, 4^{cm} long, was shaped at one end to a truncated wedge, and at the other inserted in a crossbar of wood. A copper block was held upon either face of the wedge by a light spring. Under these blocks, and pressed by them against the faces of the wedge, pass the bars of the thermo-couple, the bars meeting 1^{cm} beyond the end of the wedge, where they are soldered. The insulation between the bars, the copper blocks and the wedge was effected by a thin film of hard varnish only. It is thought that by the above means the conduction of heat to the other junctions is prevented, and at the same time the insulation was found to be complete. The thermo-junction was connected with a sensitive galvanometer and a thousand ohms additional resistance. It is assumed that the galvanometer deflections produced by the junctions through this circuit are proportional to the electromotive forces of the junctions.

The deflections were produced as follows. Two beakers of water were provided, one at the temperature of the room, the other at a higher temperature. The water in each was at such a level that when the crossbar above spoken of rested upon the rim of the beakers the junction would project a little below the surface of the water. Then the water in each having been stirred and its temperature read off, the junction was shifted quickly from one beaker to the other, and, after the swing of the galvanometer needle, back again. The deflection produced by each couple under experiment was compared in each case with the deflection by a couple of fine iron and copper wires adopted as a standard. The electromotive force of the standard junction was obtained by comparisons with a standard Daniels cell, and found to be 1412 C. G. S. units at a temperature of 30° mean.

Materials and preparation.

The bismuth was prepared by Joseph Torrey of the Harvard chemical laboratory. Mr. Torrey has made the preparation of pure bismuth a special study with a view to the re-determination of its atomic weight. It is freed from lead only with great difficulty, and it is worthy of note that the samples used do not show the lines of that impurity in the spark spectrum.

The antimony employed was a portion of that prepared by Professor Cook for his research upon its atomic weights. The lead, which was made one element in all the junctions, was prepared by electrolysis from the pure acetate.

The metals are cast in thin laminæ as follows. Two pieces of plate glass are smoked slightly, or are very finely ground and rubbed with plumbago. The metal being melted upon charcoal or under fused sodium chloride, a little pool is poured upon one plate and the other is applied to it as quickly as possible. In this way a leaf of very small thickness is obtained, which can be cut into narrow strips with a straight-edge and a thin graver.

Results.

The following table gives in column a the composition of the alloy forming one element of the junction, the other element being pure lead; in t the mean temperature of the hot and cold junctions; in t' the difference of temperature; in d the galvanometer deflection per degree difference of temperature: in h the thermo-electric height relative to lead. The signs in column h are in accordance with the convention that for the Peltier effect a current running down generates heat.

a		t	t'	d	h
Bi	Sb				
50	50	32·0	18·5	1·960	— 1845
60	40	31·0	25·1	3·127	2944
70	30	31·4	24·2	4·230	3982
80	20	31·0	22·7	5·710	5374
90	10	32·0	21·5	6·576	6179
95	5	31·2	24·5	7·205	6782
97·5	2·5	30·3	22·5	7·220	6796
98·75	1·25	29·6	24·6	5·558	5232
Commercial Bi		30·6	25·2	4·323	4069
Pure Bi		33·0	26·0	6·869	6466

a		*t*	*t'*	*d*		*h*
Bi	Sn					
50	50	28·9	25·7	0·929	+	875
60	40	32·1	21·2	1·333		1255
70	30	32·0	20·0	2·139		2014
80	20	29·9	25·2	3·109		2926
90	10	31·5	23·1	4·790		4509
95	5	31·5	23·1	4·850		4562
97·5	2·5	30·3	26·7	4·400		4134
98·75	1·25	30·0	26·1	3·556		3348
99·25	0·75	30·6	25·1	1·376		1296
99·62	0·37	30·0	23·0	0·044		41
Sn	Sb					
0	100	33·0	26·0	3·462	+	3267
5	95	29·6	25·7	0·845		793
10	90	30·0	29·5	0·824		777
20	80	28·4	27·7	1·496		1408
30	70	28·0	28·0	1·296		1220
40	60	28·1	28·2	1·330		1254
50	50	31·1	23·3	0·652		614
70	30	31·7	22·4	0·229		216
80	20	30·9	19·8	0·113		107
Commercial Sb		30·0	30·4	2·678		2520
Cd	Bi					
0·25	99·75	28·8	26·7	3·260	+	3801
0·50	99·50	29·9	30·7	3·460		4057
1·00	99·00	31·7	20·5	2·750		3207
1·25	98·75	29·2	27·5	2·710		3160
2·50	97·50	31·9	18·8	2·260		2642
5·00	95·00	28·7	23·4	1·740		2000
10·0	90·00	30·4	23·8	1·202		1401
20·0	80·00	31·9	19·8	0·424		495
100·	0·00	29·5	21·1	0·296		345

An inspection of the table shows that the best combination for a thermo-junction from these alloys is,—for one element bismuth with from two to five per cent antimony; and for the other bismuth with from five to ten per cent tin. Both of these alloys are easily cast into very thin leaves by the method above described, and can then be worked with a fine file as thin as 0·03^{mm} and are sufficiently tough to stand ordinary treatment.

According to Boys the Elliot Bros. instrument makers, use in their thermopiles alloys of bismuth thirty-two parts, antimony one part, and bismuth twelve parts, tin one part.

A junction of two very thin bars of bismuth with two per cent antimony, and bismuth with ten per cent tin (which on the whole seem to be the best combination) exhibited the following properties:

Mean temp. of junctions	7°·3	17°·0	22°·0	31°·5	36°·7
E. M. F. per degree	11150	11670	12050	12410	12630

Plotting these points we find them to lie nearly upon a straight line, from the slope of which we get, for ordinary temperature, the electromotive force of this junction:—$10700+41t$. C. G. S. units.

Bismuth and Selenium.

Melted $0{\cdot}5^{gm}$ selenium and 15^{gm} bismuth at first formed a pasty mass which became fluid only above a red heat. It was easily cast into leaves; extremely brittle and soldered with difficulty. The combination was evidently a mixture rather than a true alloy, for when allowed to cool slowly most of the selenium separated. Several of these mixtures were tested but were found to exhibit but feeble electromotive force,—less than half that of the iron-copper junction.

Bowdoin College, May, 1894.

ART. XXXIII.—*On the Magnitude of the Solar System;* being the address delivered before the American Association for the Advancement of Science at its Brooklyn meeting, August 16, 1894, by the retiring president, WM. HARKNESS.

NATURE may be studied in two widely different ways. On the one hand we may employ a powerful microscope which will render visible the minutest forms and limit our field of view to an infinitessimal fraction of an inch situated within a foot of our own noses; or on the other hand, we may occupy some commanding position and from thence, aided perhaps by a telescope, we may obtain a comprehensive view of an extensive region. The first method is that of the specialist, the second is that of the philosopher, but both are necessary for an adequate understanding of nature. The one has brought us knowledge wherewith to defend ourselves against bacteria and microbes which are among the most deadly enemies of mankind, and the other has made us acquainted with the great laws of matter and force upon which rests the whole fabric of science. All nature is one, but for convenience of classification we have

divided our knowledge into a number of sciences which we usually regard as quite distinct from each other. Along certain lines, or more properly, in certain regions, these sciences necessarily abut on each other, and just there lies the weakness of the specialist. He is like a wayfarer who always finds obstacles in crossing the boundaries between two countries, while to the traveler who gazes over them from a commanding eminence the case is quite different. If the boundary is an ocean shore there is no mistaking it; if a broad river or a chain of mountains it is still distinct; but if only a line of posts traced over hill and dale, then it becomes lost in the natural features of the landscape, and the essential unity of the whole region is apparent. In that case the border land is wholly a human conception of which nature takes no cognizance, and so it is with the scientific border land to which I propose to invite your attention this evening.

To the popular mind there are no two sciences further apart than astronomy and geology. The one treats of the structure and mineral constitution of our earth, the causes of its physical features and its history, while the other treats of the celestial bodies, their magnitudes, motions, distances, periods of revolution, eclipses, order, and of the causes of their various phenomena. And yet many, perhaps I may even say most of the apparent motions of the heavenly bodies are merely reflections of the motions of the earth, and in studying them we are really studying it. Furthermore, precession, nutation and the phenomena of the tides depend largely upon the internal structure of the earth, and there astronomy and geology merge into each other. Nevertheless the methods of the two sciences are widely different, most astronomical problems being discussed quantitatively by means of rigid mathematical formulæ, while in the vast majority of cases the geological ones are discussed only qualitatively, each author contenting himself with a mere statement of what he thinks. With precise data the methods of astronomy lead to very exact results, for mathematics is a mill which grinds exceeding fine; but after all, what comes out of a mill depends wholly upon what is put into it, and if the data are uncertain, as is the case in most cosmological problems, there is little to choose between the mathematics of the astronomer and the guesses of the geologist.

If we examine the addresses delivered by former presidents of this Association, and of the sister—perhaps it would be nearer the truth to say the parent Association on the other side of the Atlantic, we shall find that they have generally dealt either with the recent advances in some broad field of science, or else with the development of some special subject. This evening I propose to adopt the latter course, and I shall invite

your attention to the present condition of our knowledge respecting the magnitude of the solar system, but in so doing it will be necessary to introduce some considerations derived from laboratory experiments upon the luminiferous ether, others derived from experiments upon ponderable matter, and still others relating both to the surface phenomena and to the internal structure of the earth, and thus we shall deal largely with the border land where astronomy, physics and geology merge into each other.

The relative distances of the various bodies which compose the solar system can be determined to a considerable degree of approximation with very crude instruments as soon as the true plan of the system becomes known, and that plan was taught by Pythagoras more than five hundred years before Christ. It must have been known to the Egyptians and Chaldeans still earlier, if Pythagoras really acquired his knowledge of astronomy from them as is affirmed by some of the ancient writers, but on that point there is no certainty. In public Pythagoras seemingly accepted the current belief of his time, which made the earth the center of the universe, but to his own chosen disciples he communicated the true doctrine that the sun occupies the center of the solar system, and that the earth is only one of the planets revolving around it. Like all the world's greatest sages, he seems to have taught only orally. A century elapsed before his doctrines were reduced to writing by Philolaus of Crotona, and it was still later before they were taught in public for the first time by Hicetas, or as he is sometimes called Nicetas, of Syracuse. Then the familiar cry of impiety was raised, and the Pythagorean system was eventually suppressed by that now called the Ptolemaic which held the field until it was overthrown by Copernicus almost two thousand years later. Pliny tells us that Pythagoras believed the distances to the sun and moon to be respectively 252,000 and 12,600 stadia, or taking the stadium at 625 feet, 29,837 and 1492 English miles; but there is no record of the method by which these numbers were ascertained.

After the relative distances of the various planets are known, it only remains to determine the scale of the system, for which purpose the distance between any two planets suffices. We know little about the early history of the subject, but it is clear that the primitive astronomers must have found the quantities to be measured too small for detection with their instruments, and even in modern times the problem has proved to be an extremely difficult one. Aristarcus of Samos who flourished about 270 B. C. seems to have been the first to attack it in a scientific manner. Stated in modern language, his reasoning was that when the moon is exactly half full, the earth and sun

as seen from its center must make a right angle with each other, and by measuring the angle between the sun and moon, as seen from the earth at that instant, all the angles of the triangle joining the earth, sun and moon would become known, and thus the ratio of the distance of the sun to the distance of the moon would be determined. Although perfectly correct in theory, the difficulty of deciding visually upon the exact instant when the moon is half full is so great that it cannot be accurately done even with the most powerful telescopes. Of course Aristarcus had no telescope, and he does not explain how he effected the observation, but his conclusion was that at the instant in question the distance between the centers of the sun and moon, as seen from the earth, is less than a right angle by $\frac{1}{30}$ part of the same. We should now express this by saying that the angle is 87 degrees, but Aristarcus knew nothing of trigonometry, and in order to solve his triangle, he had recourse to an ingenious, but long and cumbersome geometrical process which has come down to us, and affords conclusive proof of the condition of Greek mathematics at that time. His conclusion was that the sun is nineteen times further from the earth than the moon, and if we combine that result with the modern value of the moon's parallax, viz: 3422·38 seconds, we obtain for the solar parallax 180 seconds, which is more than twenty times too great.

The only other method of determining the solar parallax known to the ancients was that devised by Hipparchus about 150 B. C. It was based on measuring the rate of decrease of the diameter of the earth's shadow cone by noting the duration of lunar eclipses, and as the result deduced from it happened to be nearly the same as that found by Aristarcus, substantially his value of the parallax remained in vogue for nearly two thousand years, and the discovery of the telescope was required to reveal its erroneous character. Doubtless this persistency was due to the extreme minuteness of the true parallax, which we now know is far too small to have been visible upon the ancient instruments, and thus the supposed measures of it were really nothing but measures of their inaccuracy.

The telescope was first pointed to the heavens by Galileo in 1609, but it needed a micrometer to convert it into an accurate measuring instrument, and that did not come into being until 1639 when it was invented by Wm. Gascoigne. After his death in 1644, his original instrument passed to Richard Townley who attached it to a fourteen foot telescope at his residence in Townley, Lancashire, England, where it was used by Flamsteed in observing the diurnal parallax of Mars during its opposition in 1672. A description of Gascoigne's micrometer was published in the Philosophical Transactions in 1667, and

a little before that a similar instrument had been invented by Auzout in France, but observatories were fewer then than now, and so far as I know J. D. Cassini was the only person beside Flamsteed who attempted to determine the solar parallax from that opposition of Mars. Foreseeing the importance of the opportunity, he had Richer dispatched to Cayenne some months previously, and when the opposition came he effected two determinations of the parallax; one being by the diurnal method, from his own observations in Paris, and the other by the meridian method, from observations in France by himself, Römer and Picard, combined with those of Richer at Cayenne. This was the transition from the ancient instruments with open sights to telescopes armed with micrometers, and the result must have been little short of stunning to the seventeenth century astronomers, for it caused the hoary and gigantic parallax of about 180 seconds to shrink incontinently to ten seconds, and thus expanded their conception of the solar system to something like its true dimensions. More than fifty years previously Kepler had argued from his ideas of the celestial harmonies that the solar parallax could not exceed 60 seconds, and a little later Horrocks had shown on more scientific grounds that it was probably as small as 14 seconds, but the final death blow to the ancient values ranging as high as two or three minutes came from these observations of Mars by Flamsteed, Cassini and Richer.

Of course the results obtained in 1672 produced a keen desire on the part of astronomers for further evidence respecting the true value of the parallax, and as Mars comes into a favorable position for such investigations only at intervals of about sixteen years, they had recourse to observations of Mercury and Venus. In 1677 Halley observed the diurnal parallax of Mercury, and also a transit of that planet across the sun's disk, at St. Helena, and in 1681 J. D. Cassini and Picard observed Venus when she was on the same parallel with the sun, but although the observations of Venus gave better results than those of Mercury, neither of them was conclusive, and we now know that such methods are inaccurate even with the powerful instruments of the present day. Nevertheless Halley's attempt by means of the transit of Mercury ultimately bore fruit in the shape of his celebrated paper of 1716, wherein he showed the peculiar advantages of transits of Venus for determining the solar parallax. The idea of utilizing such transits for this purpose seems to have been vaguely conceived by James Gregory, or perhaps even by Horrocks, but Halley was the first to work it out completely, and long after his death his paper was mainly instrumental in inducing the governments of Europe to undertake the observations of the

transits of Venus in 1761 and 1769, from which our first accurate knowledge of the sun's distance was obtained.

Those who are not familiar with practical astronomy may wonder why the solar parallax can be got from Mars and Venus, but not from Mercury, or the sun itself. The explanation depends on two facts. Firstly, the nearest approach of these bodies to the earth is for Mars 33,874,000 miles, for Venus 23.654,000 miles, for Mercury 47,935,000 miles and for the sun 91,239,000 miles. Consequently, for us Mars and Venus have very much larger parallaxes than Mercury or the sun, and of course the larger the parallax the easier it is to measure. Secondly, even the largest of these parallaxes must be determined within far less than one-tenth of a second of the truth, and while that degree of accuracy is possible in measureing short arcs, it is quite unattainable in long ones. Hence one of the most essential conditions for the successful measurement of parallaxes is that we shall be able to compare the place of the near body with that of a more distant one situated in the same region of the sky. In the case of Mars that can always be done by making use of a neighboring star, but when Venus is near the earth she is also so close to the sun that stars are not available, and consequently her parallax can be satisfactorily measured only when her position can be accurately referred to that of the sun, or in other words, only during her transits across the sun's disk. But even when the two bodies to be compared are sufficiently near each other, we are still embarrassed by the fact that it is more difficult to measure the distance between the limb of a planet and a star or the limb of the sun than it is to measure the distance between two stars, and since the discovery of so many asteroids, that circumstance has led to their use for determinations of the solar parallax. Some of these bodies approach within 75,230,000 miles of the earth's orbit, and as they look precisely like stars, the increased accuracy of pointing on them fully makes up for their greater distance, as compared with Mars or Venus.

After the Copernican system of the world and the Newtonian theory of gravitation were accepted it soon became evident that trigonometrical measurements of the solar parallax might be supplemented by determinations based on the theory of gravitation, and the first attempts in that direction were made by Machin in 1729 and T. Mayer in 1753. The measurement of the velocity of light between points on the earth's surface, first effected by Fizeau in 1849, opened up still other possibilities, and thus for determining the solar parallax we now have at our command no less than three entirely distinct classes of methods which are known respectively as the trigonometrical, the gravitational and the photo-tachymetrical. We have

already given a summary sketch of the trigonometrical methods, as applied by the ancient astronomers to the dichotomy and shadow cone of the moon, and by the moderns, to Venus, Mars and the asteroids, and we shall next glance briefly at the gravitational and photo-tachymetrical methods.

The gravitational results which enter directly or indirectly into the solar parallax are six in number, to wit: first, the relation of the moon's mass to the tides; second, the relation of the moon's mass and parallax to the force of gravity at the earth's surface; third, the relation of the solar parallax to the masses of the earth and moon; fourth, the relation of the solar and lunar parallaxes to the moon's mass and parallactic inequality; fifth, the relation of the solar and lunar parallaxes to the moon's mass and the earth's lunar inequality; sixth, the relation of the constants of nutation and precession to the moon's parallax.

Respecting the first of these relations it is to be remarked that the tide-producing forces are the attraction of the sun and moon upon the waters of the ocean, and from the ratio of these attractions the moon's mass can readily be determined. But unfortunately the ratio of the solar tides to the lunar tides is affected both by the depth of the sea and by the character of the channels through which the water flows, and for that reason the observed ratio of these tides requires multiplication by a correcting factor in order to convert it into the ratio of the forces. The matter is further complicated by this correcting factor varying from port to port, and in order to get satisfactory results long series of observations are necessary. The labor of deriving the moon's mass in this way was formerly so great that for more than half a century La Place's determination from the tides at Brest remained unique, but the recent application of harmonic analysis to the data supplied by self-registering tide gauges is likely to yield abundant results in the near future.

Our second gravitational relation, viz: that connecting the moon's mass and parallax with the force of gravity at the earth's surface, affords an indirect method of determining the moon's parallax with very great accuracy if the computation is carefully made, and with a fair approximation to the truth even when the data are exceedingly crude. To illustrate this, let us see what could be done with a railroad transit such as is commonly used by surveyors, a steel tape, and a fairly good watch. Neglecting small corrections due to the flattening of the earth, the centrifugal force at its surface, the eccentricity of its orbit, and the mass of the moon; the law of gravitation shows that if we multiply together the length of the seconds pendulum, the square of the radius of the earth, and the square

of the length of the sidereal month, divide the product by four, and take the cube root of the quotient, the result will be the distance from the earth to the moon. To find the length of the seconds pendulum we would rate the watch by means of the railroad transit, and then making a pendulum out of a spherical leaden bullet suspended by a fine thread, we would adjust the length of the thread until the pendulum made exactly 300 vibrations in five minutes by the watch. Then, supposing the experiment to be made here, or in New York City, we would find that the distance from the point of suspension of the thread to the center of the bullet was about 39⅛ inches, and dividing that by the number of inches in a mile, viz: 63,360, we would have for the length of the seconds pendulum one sixteen hundred and twentieth of a mile. The next step would be to ascertain the radius of the earth, and the quickest way of doing so would probably be, first to determine the latitude of some point in New York City by means of the railroad transit, next to run a traverse survey along the old Post Road from New York to Albany, and finally to determine the latitude of some point in Albany. The traverse survey should surely be correct to one part in three hundred, and as the distance between the two cities is about two degrees, the difference of latitude might be determined to about the same percentage of accuracy. In that way we would find the length of two degrees of latitude to be about 138 miles, whence the earth's radius would be 3953 miles. It would then only remain to observe the time occupied by the moon in making a sidereal revolution around the earth, or in other words the time which she occupies in moving from any given star back to the same star again. By noting that to within one-quarter of her own diameter we would soon find that the time of a revolution is about 27·32 days, and multiplying that by the number of seconds in a day, viz: 86,400, we would have for the length of the sidereal month 2,360,000 seconds. With these data the computation would stand as follows; the radius of the earth, 3953 miles, multiplied by the length of a sidereal month, 2,360,000 seconds, and the product squared, gives 87,060,000,000,000,000,000. Multiplying that by one-fourth of the length of the seconds pendulum, viz: 1/6480 of a mile, and extracting the cube root of the product, we would get 237,700 miles for the distance from the earth to the moon, which is only about 850 miles less than the truth, and is certainly a remarkable result considering the crudeness of the instruments by which it might be obtained. Nevertheless, when all the conditions are rigorously taken into account these data are to be regarded as determining the relation between the moon's mass and parallax rather than the parallax itself.

Our third gravitational relation, to wit: that existing between the solar parallax, the solar attractive force and the masses of the earth and moon, is analogous to the relation existing between the moon's mass and parallax and the force of gravity at the earth's surface, but it can not be applied in exactly the same way on account of our inability to swing a pendulum on the sun. We are therefore compelled to adopt some other method of determining the sun's attractive force, and the most available is that which consists in observing the perturbative action of the earth and moon upon our nearest planetary neighbors, Venus and Mars. From this action the law of gravitation enables us to determine the ratio of the sun's mass to the combined masses of the earth and moon, and then the relation in question furnishes a means of comparing the masses so found with trigonometrical determinations of the solar parallax. Thus it appears that notwithstanding necessary differences in the methods of procedure, the analogy between the second and third gravitational relations holds not only with respect to their theoretical basis, but also in their practical application, the one being used to determine the relation between the mass of the moon and its distance from the earth, and the other to determine the relation between the combined masses of the earth and moon and their distance from the sun.

Our fourth gravitational relation deals with the connection between the solar parallax, the lunar parallax, the moon's mass and the moon's parallactic inequality. The important quantities are here the solar parallax and the moon's parallactic inequality, and although the derivation of the complete expression for the connection between them is a little complicated, there is no difficulty in getting a general notion of the forces involved. As the moon moves around the earth she is alternately without and within the earth's orbit. When she is without, the sun's attraction on her acts with that of the earth; when she is within, the two attractions act in opposite directions. Thus in effect the centripetal force holding the moon to the earth is alternately increased and diminished, with the result of elongating the moon's orbit towards the sun and compressing it on the opposite side. As the variation of the centripetal force is not great, the change of form of the orbit is small, nevertheless the summation of the minute alterations thereby produced in the moon's orbital velocity suffices to put her sometimes ahead, and sometimes behind her mean place to an extent which oscillates from a maximum to a minimum as the earth passes from perihelion to aphelion, and averages about 125 seconds of arc. This perturbation of the moon is known as the parallactic inequality because it depends on the earth's distance from the sun, and can therefore be expressed

in terms of the solar parallax. Conversely, the solar parallax can be deduced from the observed value of the parallactic inequality, but unfortunately there are great practical difficulties in making the requisite observations with a sufficient degree of accuracy. Notwithstanding the ever recurring talk about the advantages to be obtained by observing a small well defined crater instead of the moon's limb, astronomers have hitherto found it impracticable to use anything but the limb, and the disadvantage of doing so as compared with observing a star is still further increased by the circumstance that in general only one limb can be seen at a time, the other being shrouded in darkness. If both limbs could always be observed we should then have a uniform system of data for determining the place of the center, but under existing circumstances we are compelled to make our observations half upon one limb and half upon the other, and thus they involve all the systematic errors which may arise from the conditions under which these limbs are observed, and all the uncertainty which attaches to irradiation, personal equation, and our defective knowledge of the moon's semi-diameter.

Our fifth gravitational relation is that which exists between the solar parallax, the lunar parallax, the moon's mass and the earth's lunar inequality. Strictly speaking the moon does not revolve around the earth's center, but both bodies revolve around the common center of gravity of the two. In consequence of that an irregularity arises in the earth's orbital velocity around the sun, the common center of gravity moving in accordance with the laws of elliptic motion, while the earth, on account of its revolution around that center, undergoes an alternate acceleration and retardation which has for its period a lunar month, and is called the lunar inequality of the earth's motion. We perceive this inequality as an oscillation superposed on the elliptic motion of the sun, and its semi-amplitude is a measure of the angle subtended at the sun by the interval between the center of the earth and the common center of gravity of the earth and moon. Just as an astronomer on the moon might use the radius of her orbit around the earth as a base for measuring her distance from the sun, so we may use this interval for the same purpose. We find its length in miles from the equatorial semi-diameter of the earth, the moon's parallax and the moon's mass, and thus we have all the data for determining the solar parallax from the inequality in question. In view of the great difficulty which has been experienced in measuring the solar parallax itself, it may be asked why we should attempt to deal with the parallactic inequality which is about twenty-six per cent smaller? The answer is, because the latter is derived from differences of the sun's right

ascension which are furnished by the principal observatories in vast numbers, and should give very accurate results on account of their being made by methods which insure freedom from constant errors. Nevertheless, the sun is not so well adapted for precise observation as the stars, and Dr. Gill has recently found that heliometer measurements upon asteroids which approach very near to the earth yield values of the parallactic inequality superior to those obtained from right ascensions of the sun.

Our sixth gravitational relation is that which exists between the moon's parallax and the constants of precession and nutation. Every particle of the earth is attracted both by the sun and by the moon, but in consequence of the polar flattening the resultant of these attractions passes a little to one side of the earth's center of gravity. Thus a couple is set up, which, by its action upon the rotating earth, causes the axis thereof to describe a surface which may be called a fluted cone, with its apex at the earth's center. A top spinning with its axis inclined describes a similar cone, except that the flutings are absent and the apex is at the point upon which the spinning occurs. For convenience of computation we resolve this action into two components, and we name that which produces the cone the luni-solar precession, and that which produces the flutings the nutation. In this phenomenon the part played by the sun is comparatively small, and by eliminating it we obtain a relation between the luni-solar precession, the nutation and the moon's parallax which can be used to verify and correct the observed values of these quantities.

In the preceding paragraph we have seen that the relation between the quantities there considered depends largely upon the flattening of the earth, and thus we are led to inquire how and with what degree of accuracy that is determined. There are five methods, viz: one geodetic, one gravitational, and three astronomical. The geodetic method depends upon measurements of the length of a degree on various parts of the earth's surface, and with the data hitherto accumulated it has proved quite unsatisfactory. The gravitational method consists in determining the length of the seconds pendulum over as great a range of latitude as possible, and deducing therefrom the ratio of the earth's polar and equatorial semi-diameters by means of Clairaut's theorem. The pendulum experiments show that the earth's crust is less dense on mountain plateaux than at the sea coast, and thus for the first time we are brought into contact with geological considerations. The first astronomical method consists in observing the moon's parallax from various points on the earth's surface, and as these parallaxes are nothing else than the angular semi-diameter of the earth at

the respective points as seen from the moon, they afford a direct measure of the flattening. The second and third astronomical methods are based upon certain perturbations of the moon which depend upon the figure of the earth, and should give extremely accurate results, but unfortunately very great difficulties oppose themselves to the exact measurement of the perturbations. There is also an astronomico-geological method which can not yet be regarded as conclusive on account of our lack of knowledge respecting the law of density which prevails in the interior of the earth. It is based upon the fact that a certain function of the earth's moments of inertia can be determined from the observed values of the coefficients of precession and nutation, and could also be determined from the figure and dimensions of the earth if we knew the exact distribution of matter in its interior. Our present knowledge on that subject is limited to a superficial layer not more than ten miles thick, but it is usual to assume that the deeper matter is distributed according to La Grange's law, and then by writing the function in question in a form which leaves the flattening indeterminate, and equating the expression so found to the value given by the precession and nutation, we readily obtain the flattening. As yet these six methods do not give consistent results, and so long as serious discrepancies remain between them there can be no security that we have arrived at the truth.

It should be remarked that in order to compute the function of the earth's moments of inertia which we have just been considering, we require not only the figure and dimensions of the earth and the law of distribution of density in its interior, but also its mean and surface densities. The experiments for determining the mean density have consisted in comparing the earth's attraction with the attraction either of a mountain, or of a known thickness of the earth's crust, or of a known mass of metal. In the case of mountains the comparisons have been made with plumb lines and pendulums; in the case of known layers of the earth's crust they have been made by swinging pendulums at the surface and down in mines; and in the case of known masses of metal they have been made with torsion balances, fine chemical balances and pendulums. The surface density results from a study of the materials composing the earth's crust, but notwithstanding the apparant simplicity of that process, it is doubtful if we have yet attained as accurate a result as in the case of the mean density.

Before quitting this part of our subject, it is important to point out that the luni-solar precession can not be directly observed, but must be derived from the general precession. The former of these quantities depends only upon the action

of the sun and moon, while the latter is affected in addition by the action of the planets, and to ascertain what that is we must determine their masses. The methods of doing so fall into two great classes according as the planets dealt with have or have not satellites. The most favorable case is that in which one or more satellites are present, because the mass of the primary follows immediately from their distances and revolution times, but even then there is a difficulty in the way of obtaining very exact results. By extending the observations over sufficiently long periods the revolution times can be ascertained with any desired degree of accuracy, but all measurements of the distance of a satellite from its primary are affected by personal equation, which we can not be sure of completely eliminating, and thus a considerable margin of uncertainty is brought into the masses. In the cases of Mercury and Venus, which have no satellites, and to a certain extent in the case of the earth also, the only available way of ascertaining the masses is from the perturbations produced by the action of the various planets on each other. These perturbations are of two kinds, periodic and secular. When sufficient data have been accumulated for the exact determination of the secular perturbations, they will give the best results, but as yet it remains advantageous to employ the periodic perturbations also.

Passing now to the photo-tachymetrical methods, we have first to glance briefly at the mechanical appliances by which the tremendous velocity of light has been successfully measured They are of the simplest possible character, and are based either upon a toothed wheel, or upon a revolving mirror.

The toothed wheel method was first used by Fizeau in 1849. To understand its operation, imagine a gun barrel with a toothed wheel revolving at right angles to its muzzle in such a way that the barrel is alternately closed and opened as the teeth and the spaces between them pass before it. Then, with the wheel in rapid motion, at the instant when a space is opposite the muzzle let a ball be fired. It will pass out freely, and after traversing a certain distance let it strike an elastic cushion and be reflected back upon its own path. When it reaches the wheel, if it hits a space it will return into the gun barrel, but if it hits a tooth it will be stopped. Examining the matter a little more closely, we see that as the ball requires a certain time to go and return, if during that time the wheel moves through an odd multiple of the angle between a space and a tooth the ball will be stopped, while if it moves through an even multiple of that angle the ball will return into the barrel. Now imagine the gun barrel, the ball and the elastic cushion to be replaced respectively by a telescope, a light wave and a mirror. Then if the wheel moved at such a speed that the

returning light wave struck against the tooth following the space through which it issued, to an eye looking into the telescope all would be darkness. If the wheel moved a little faster and the returning light wave passed through the space succeeding that through which it issued, the eye at the telescope would perceive a flash of light; and if the speed were continuously increased a continual succession of eclipses and illuminations would follow each other according as the returning light was stopped against a tooth or passed through a space further and further behind that through which it issued. Under these conditions the time occupied by the light in traversing the space from the wheel to the mirror and back again would evidently be the same as the time required by the wheel to revolve through the angle between the space through which the light issued and that through which it returned, and thus the velocity of light would become known from the distance between the telescope and the mirror together with the speed of the wheel. Of course the longer the distance traversed, and the greater the velocity of the wheel, the more accurate would be the result.

The revolving mirror method was first used by Foucault in 1862. Conceive the toothed wheel of Fizeau's apparatus to be replaced by a mirror attached to a vertical axis, and capable of being put into rapid rotation. Then it will be possible so to arrange the apparatus that light issuing from the telescope shall strike the movable mirror and be reflected to the distant mirror, whence it will be returned to the movable mirror again and being thrown back into the telescope will appear as a star in the center of the field of view. That adjustment being made, if the mirror were caused to revolve at a speed of some hundred turns per second it would move through an appreciable angle while the light was passing from it to the distant mirror and back again, and in accordance with the laws of reflection, the star in the field of the telescope would move from the center by twice the angle through which the mirror had turned. Thus the deviation of the star from the center of the field would measure the angle through which the mirror turned during the time occupied by light in passing twice over the interval between the fixed and revolving mirrors, and from the magnitude of that angle together with the known speed of the mirror, the velocity of the light could be calculated.

In applying either of these methods the resulting velocity is that of light when traversing the earth's atmosphere, but what we want is its velocity in space which we suppose to be destitute of ponderable material, and in order to obtain that the velocity in the atmosphere must be multiplied by the refractive index of air. The corrected velocity so obtained can then be

used to find the solar parallax, either from the time required by light to traverse the semi-diameter of the earth's orbit, or from the ratio of the velocity of light to the orbital velocity of the earth.

Any periodic correction which occurs in computing the place of a heavenly body, or the time of a celestial phenomenon, is called by astronomers, an equation, and as the time required by light to traverse the semi-diameter of the earth's orbit first presented itself in the guise of a correction to the computed times of the eclipses of Jupiter's satellites, it has received the name of the light equation. The earth's orbit being interior to that of Jupiter, and both having the sun for their center, it is evident that the distance between the two planets must vary from the sum to the difference of the radii of their respective orbits, and the time required by light to travel from one planet to the other must vary proportionately. Consequently, if the observed times of the eclipses of Jupiter's satellites are compared with the times computed upon the assumption that the two planets are always separated by their mean distance it will be found that the eclipses occur too early when the earth is at less than its mean distance from Jupiter, and too late when it is further off, and from large numbers of such observations the value of the light equation has been deduced.

The combination of the motion of light through our atmosphere with the orbital motion of the earth gives rise to the annual aberration, all the phases of which are computed from its maximum value, commonly called the constant of aberration. There is also a diurnal aberration due to the rotation of the earth on its axis, but that is quite small and does not concern us this evening. When aberration was discovered the corpuscular theory of light was in vogue, and it offered a charmingly simple explanation of the whole phenomenon. The hypothetical light corpuscles impinging upon the earth were thought to behave precisely like the drops in a shower of rain, and you all know that their apparent direction is affected by any motion on the part of the observer. In a calm day when the drops are falling perpendicularly, a man standing still holds his umbrella directly over his head, but as soon as he begins to move forward he inclines his umbrella in the same direction, and the more rapidly he moves the greater must be its inclination in order to meet the descending shower. Similarly, the apparent direction of an oncoming light corpuscle would be affected by the orbital motion of the earth, so that in effect it would always be the resultant arising from combining the motion of the light with a motion equal and opposite to that of the earth. But since the falsity of the corpuscular theory has been proved that explanation is no longer tenable,

and as yet we have not been able to replace it with anything equally satisfactory based on the now universally accepted undulatory theory. In accordance with the latter theory we must conceive the earth as plowing its way through the ether, and the point which has hitherto baffled us is whether or not in so doing it produces any disturbance of the ether which affects the aberration. In our present ignorance on that point we can only say that the aberration constant is certainly very nearly equal to the ratio of the earth's orbital velocity to the velocity of light, but we can not affirm that it is rigorously so.

The luminiferous ether was invented to account for the phenomena of light, and for two hundred years it was not suspected to have any other function. The emission theory postulated only the corpuscles which constitute light itself, but the undulatory theory fills all space with an imponderable substance possessing properties even more remarkable than those of ordinary matter, and to some of the acutest intellects the magnitude of this idea has proved an almost insuperable objection against the whole theory. So late as 1862 Sir David Brewster, who had gained a world-wide reputation by his optical researches, expressed himself as staggered by the notion of filling all space with some substance merely to enable a little twinkling star to send its light to us; but not long after Clerk Maxwell removed that difficulty by a discovery coextensive with the undulatory theory itself. Since 1845, when Faraday first performed his celebrated experiment of magnetising a ray of light, the idea that electricity is a phenomenon of the ether had been steadily growing, until at last Maxwell perceived that if such were the fact the rate of propagation of an electromagnetic wave must be the same as the velocity of light. At that time no one knew how to generate such waves, but Maxwell's theory showed him that their velocity must be equal to the number of electric units of quantity in the electromagnetic unit, and careful experiments soon proved that that is the velocity of light. Thus it was put almost beyond the possibility of doubt that the ether gives rise to the phenomena of electricity and magnetism as well as to those of light, and perhaps it may even be concerned in the production of gravitation itself. What could be apparently more remote than these electric quantities and the solar parallax? And yet we have here a relation between them, but we make no use of it because as yet the same relation can be far more accurately determined from experiments upon the velocity of light.

Now let us recall the quantities and methods of observation which we have found to be involved either directly or indirectly with the solar parallax. They are, the solar parallax,

obtained from transits of Venus, oppositions of Mars and oppositions of certain asteriods; the lunar parallax, found both directly, and from measurements of the force of gravity at the earth's surface; the constants of precession, nutation and aberration, obtained from observations of the stars; the parallactic inequality of the moon; the lunar inequality of the earth, usually obtained from observations of the sun, but recently found from heliometer observations of certain asteriods: the mass of the earth, found from the solar parallax, and also from the periodic and secular perturbations of Venus and Mars; the mass of the moon, found from the lunar inequality of the earth, and also from the ratio of the solar and lunar components of the ocean tides; the masses of all the planets, obtained from observations of their satellites whenever possible, and when no satellites exist, then from observations of their mutual perturbations both periodic and secular; the velocity of light, obtained from experiments with revolving mirrors and toothed wheels, together with laboratory determinations of the index of refraction of atmospheric air; the light equation, obtained from observations of the eclipses of Jupiter's satellites; the figure of the earth, obtained from geodetic triangulations, measurements of the length of the seconds pendulum in various latitudes, and observations of certain perturbations of the moon; the mean density of the earth, obtained from measurements of the attractions of mountains, from pendulum experiments in mines, and from experiments on the attraction of known masses of matter made either with torsion balances or with the most delicate chemical balances; the surface density of the earth, obtained from geological examinations of the surface strata; and lastly, the law of distribution of density in the interior of the earth, which in the present state of geological knowledge we can do little more than guess at.

Here then we have a large group of astronomical, geodetic, geological and physical quantities which must all be considered in finding the solar parallax, and which are all so entangled with each other that no one of them can be varied without affecting all the rest. It is therefore impossible to make an accurate determination of any one of them apart from the remainder of the group, and thus we are driven to the conclusion that they must all be determined simultaneously. Such has not been the practice of astronomers in the past, but it is the method to which they must inevitably resort in the future. A cursory glance at an analogous problem occurring in geodesy may be instructive. When a country is covered with a net of triangles it is always found that the observed angles are subject to a certain amount of error, and a century ago it was the habit to correct the angles in each triangle without much regard

to the effect upon adjacent triangles. Consequently the adjustment of the errors was imperfect, and in computing the interval between any two distant points the result would vary somewhat with the triangles used in the computation—that is, if one computation was made through a chain of triangles running around on the right hand side, another through a chain of triangles running straight between the two points, and a third through a chain of triangles running around on the left hand side, the results were usually all different. At that time things were less highly specialized than now, and all geodetic operations were yet in the hands of first-rate astronomers who soon devised processes for overcoming the difficulty. They imagined every observed angle to be subject to a small correction, and as these corrections were all entangled with each other through the geometrical conditions of the net, by a most ingenious application of the method of least squares they determined them all simultaneously in such a way as to satisfy the whole of the geometrical conditions. Thus the best possible adjustment was obtained, and no matter what triangles were used in passing from one point to another, the result was always the same. That method is now applied to every important triangulation, and its omission would be regarded as proof of incompetency on the part of those in charge of the work.

Now let us compare the conditions existing respectively in a triangulation net and in the group of quantities for the determination of the solar parallax. In the net every angle is subject to a small correction, and the whole system of corrections must be so determined as to make the sum of their weighted squares a minimum, and at the same time satisfy all the geometrical conditions of the net. Like the triangles, the quantities composing the group from which the solar parallax must be determined are all subject to error, and therefore we must regard each of them as requiring a small correction, and all these corrections must be so determined as to make the sum of their weighted squares a minimum, and at the same time satisfy every one of the equations expressing the relations between the various components of the group.

Thus it appears that the method required for adjusting the solar parallax and its related constants is in all respects the same as that which has so long been used for adjusting systems of triangulation, and as the latter method was invented by astronomers, it is natural to inquire why they have not applied it to the fundamental problem of their own science? The reasons are various, but they may all be classed under two heads. First, an inveterate habit of over-estimating the accuracy of our own work as compared with that of others; and second, the unfortunate effect of too much specialization.

The prevailing opinion certainly is that great advances have recently been made in astronomy, and so they have in the fields of spectral analysis and in the measurement of minute quantities of radiant heat; but the solution of the vast majority of astronomical problems depends upon the exact measurement of angles, and in that little or no progress has been made. Bradley with his zenith sector a hundred and fifty years ago, and Bessel and Struve with their circles and transit instruments seventy years ago, made observations not sensibly inferior to those of the present day, and indeed it would have been surprising if they had not done so. The essentials for accurately determining star places are a skilled observer, a clock and a transit circle, the latter consisting of a telescope, a divided circle and four micrometer microscopes. Surely no one will claim that we have to-day any more skillful observers than were Bessel, Bradley and Struve, and the only way in which we have improved upon the telescopes made by Dollond one hundred and thirty years ago, is by increasing their aperture and relatively diminishing their focal distance. The most famous dividing engine now in existence was made by the elder Repsold seventy-five years ago; but as the errors of divided circles and their micrometer microscopes are always carefully determined, the accuracy of the measured angles is quite independent of any small improvement in the accuracy of the divisions or of the micrometer screws. Only in the matter of clocks has there been some advance, and even that is not very great. On the whole, the star places of to-day are a little better than those of seventy-five years ago, but even yet there is great room for improvement. One of the commonest applications of these star places is to the determination of latitude, but it is very doubtful if there is any point on the face of the earth whose latitude is known certainly within one-tenth of a second.

Looking at the question from another point of view, it is notorious that the contact observations of the transits of Venus in 1761 and 1769 were so discordant that from the same observations Encke and E. J. Stone got respectively for the solar parallax 8·59 seconds and 8·91 seconds. In 1870 no one thought it possible that there could be any such difficulty with the contact observations of the then approaching transits of 1874 and 1882, but now we have found from sad experience that our vaunted modern instruments gave very little better results for the last pair of transits than our predecessors obtained with much cruder appliances in 1761 and 1769.

The theory of probability and uniform experience alike show that the limit of accuracy attainable with any instrument is soon reached; and yet we all know the fascination which

continually lures us on in our efforts to get better results out of the familiar telescopes and circles which have constituted the standard equipment of observatories for nearly a century. Possibly these instruments may be capable of indicating somewhat smaller quantities than we have hitherto succeeded in measuring with them, but their limit cannot be far off because they already show the disturbing effects of slight inequalities of temperature and other uncontrollable causes. So far as these effects are accidental they eliminate themselves from every long series of observations, but there always remains a residuum of constant error, perhaps quite unsuspected, which gives us no end of trouble. Encke's value of the solar parallax affords a fine illustration of this. From the transits of Venus in 1761 and 1769 he found 8·58 seconds in 1824, which he subsequently corrected to 8·57 seconds, and for thirty years that value was universally accepted. The first objection to it came from Hansen in 1854, a second followed from Le Verrier in 1858, both based upon facts connected with the lunar theory, and eventually it became evident that Encke's parallax was about one-quarter of a second too small. Now please observe that Encke's value was obtained trigonometrically, and its inaccuracy was never suspected until it was revealed by gravitational methods which were themselves in error about one-tenth of a second and required subsequent correction in other ways. Here then was a lesson to astronomers who are all more or less specialists, but it merely enforced the perfectly well known principle that the constant errors of any one method are accidental errors with respect to all other methods, and therefore the readiest way of eliminating them is by combining the results from as many different methods as possible. However, the abler the specialist the more certain he is to be blind to all methods but his own, and astronomers have profited so little by the Encke-Hansen-Le Verrier incident of thirty-five years ago that to-day they are mostly divided into two great parties, one of whom holds that the parallax can be best determined from a combination of the constant of aberration with the velocity of light, and the other believes only in the results of heliometer measurements upon asteriods. By all means continue the heliometer measurements, and do everything possible to clear up the mystery which now surrounds the constant of aberration, but why ignore the work of predecessors who were quite as able as ourselves? If it were desired to determine some one angle of a triangulation net with special exactness, what would be thought of a man who attempted to do so by repeated measurements of the angle in question while he persistently neglected to adjust the net? And yet, until recently astronomers have been doing precisely

that kind of thing with the solar parallax. I do not think there is any exaggeration in saying that the trustworthy observations now on record for the determination of the numerous quantities which are functions of the parallax could not be duplicated by the most industrious astronomer working continuously for a thousand years. How then can we suppose that the result properly deducible from them can be materially affected by anything that any of us can do in a life time, unless we are fortunate enough to invent methods of measurement vastly superior to any hitherto imagined? Probably the existing observations for the determination of most of these quantities are as exact as any that can ever be made with our present instruments, and if they were freed from constant errors they would certainly give results very near the truth. To that end we have only to form a system of simultaneous equations between all the observed quantities, and then deduce the most probable values of these quantities by the method of least squares. Perhaps some of you may think that the value so obtained for the solar parallax would depend largely upon the relative weights assigned to the various quantities, but such is not the case. With almost any possible system of weights the solar parallax will come out very nearly $8{\cdot}809'' \pm 0{\cdot}0057''$, whence we have for the mean distance between the earth and sun 92,797,000 miles, with a probable error of only 59,700 miles; and for the diameter of the solar system, measured to its outermost member, the planet Neptune, 5,578,400,000 miles.

Art. XXXIV.—*On the Nitrogen Content of California Bitumen;* by S. F. Peckham.

[Read at the Congress of Chemists held at San Francisco, Cal., in association with the Midwinter Fair, June 9th, 1894.]

In 1865, when artificial excavations in the Cañons of the Sulphur Mountain in Ventura County, California, brought to the surface bitumens that were free from the action of oxidizing agents, it was soon observed that when those bitumens were exposed in small pools for a short time they became infested with maggots. This phenomenon was observed by a number of persons. In one instance that came under my own observation, the amount of petroleum that filled a small cavity in the rocks might have been two quarts. It was so filled with maggots that they crawled over each other precisely as they would in a pool of blood. It was evident that this petroleum con-

tained the elements of food, and the presence of nitrogen was inferred as an essential constituent of this variety of bitumen.

It was several years after this observation was made before I had an opportunity to prove by analysis the actual presence and amount of nitrogen. I used the ordinary sodalime process. The amount indicated was so large that I was led to suspect that possibly some source of error lay against this process, when used for the analysis of this material. I duplicated my results on the petroleum alone. I also found no difficulty in duplicating results with one of the vegetable alkaloids, which one I do not now remember. I also obtained the proper percentage when operating upon a mixture of petroleum and alkaloid. I concluded that my results upon the petroleum alone were correct. I found that the oils from the tunnels in Wheeler's Cañon on the south side of the Sulphur Mountain yielded an average composition of:

Hydrogen	11·819	per cent.
Carbon	86·934	"
Nitrogen	1·1095	"
Total	99·8625	"

The oil of the Pico Spring contained of nitrogen 1·0165 per cent and that from the Cañada Laga spring contained of nitrogen 1·0855 per cent. Maltha from the Ojai Ranche contained of nitrogen 0·5645 per cent.* These localities lie in the line of strike of the oil-bearing formation of Ventura Co., which crosses the Santa Clara Valley in a generally east and west direction and extends parallel with the range of the Sulphur mountain. The Pico spring is in the range that forms the southern boundary of the the Santa Clara Valley. Several miles to the west and across the valley is the east end of the Sulphur mountain in which is Wheeler's Cañon. Farther west is the Cañada Laga, and in the west end of the range is the spring which furnished the maltha from the Ojai Ranche. About two years later a second determination of the nitrogen was made in the sample from Wheeler's Cañon. The amount obtained was less than one per cent but I have lost the notes of the analytical work. The two springs above named were the only springs of bitumen in Southern California that yielded a green petroleum from natural sources. I have shown in my reports to the Geological Survey of California that the oil of these springs as well as that from the tunnels in Wheeler's Cañon, which are still yielding oil, issues from strata protected

* Reports Geol. Survey Cal., Geology, II, Appendix, pp. 84, 89. Reports 10th Census U. S., vol. x, Petroleum, p. 185.

from infiltration of rain-water and accompanying oxygen, by overlying formations.

The manner in which this nitrogen is combined was not then made a subject of research. It was however my conviction at that time, based largely upon observations made upon the spot, and judged in connection with these results of analysis, that the nitrogen must in some manner be held in combination by bonds that are easily broken, and that in the re-arrangement that followed, the nitrogen content either became free, or entered more stable forms of combination, after the manner in which the process of fermentation converts complex nitrogenous compounds into simpler forms. Here this matter rested for many years.

In April, 1892, in the laboratory of the University of Michigan I distilled some of the same samples of Wheeler's Cañon petroleum in which I had determined the nitrogen more than twenty years before. The distillation was conducted at a temperature approaching the red heat and furnished products of destructive distillation. While observing the effects of various reagents upon the distillates, which I was handling in very small quantities, I noticed the very peculiar and persistent odor of pyridin. The appearance of this substance under the conditions present did not surprise me. I considered it to be a product of the destructive distillation of the petroleum at a temperature approaching the red heat.*

After I returned to California last October and made the acquaintance of Dr. Frederick Salathè, he one day showed me a small vial containing a black oil, that was in appearance Dippel's oil. He said that he had obtained the oil by washing a distillate of California petroleum with dilute sulphuric acid, and further that all of the crude oils found in the neighborhood of Santa Paula yielded basic oils to dilute sulphuric acid. Dr. Salathè seemed to be impressed with the importance of his discovery as demonstrating beyond any question the animal origin of the bitumens; a proposition to which I gave instant assent.

The importance of this discovery immediately impressed me from the technological side, and I urged the doctor to ascertain what results would follow the removal of the basic oils from the various commercial products found in the refinery.

In the laboratory I soon treated both crude oils and their distillates, and found that the basic oils in their natural condition were combined with an exceedingly viscous feebly acid tar. When the crude oils are treated with dilute acid, this acid radical forms a hydrate which produces with the other constitu-

* This Journal, vol. xlvii, p. 30, Jan. 1894.

ents of the petroleum an emulsion, from which the aqueous acid solution of the basic oils is separated with much difficulty. With many of the distillates, and particularly those of highest specific gravity, the acid radical or its hydrate does not dissolve in the oil, and the acid solution of the bases, the acid hydrate, and the oil not acted on by the dilute acid, form three distinct layers in the containing vessel. In consequence of this difference in specific gravity and solubility, the solution of the basic oils and the tar may be easily separated from the oils that originally held the salt of the basic oils in solution.

After ascertaining these facts in the laboratory, I suggested to Dr. Salathè, who then had charge of the refinery of the Union Oil Co., that the presence of these compound ethers in the California petroleums was no doubt the cause of the difficulty which had been experienced in refining them.

Steps were immediately taken to test the correctness of this judgment with the most gratifying results; but it is only very recently and under my own direction that the complete removal of both the basic and acid radicals of these ethers has been carried out on the large scale, in such a manner as fully to demonstrate the great importance of this discovery to the technology of this class of bitumens.

No complete analysis of any of the hydrocarbons that make up California petroleum has yet been made to my knowledge; but it has been assumed on other grounds that they belong to the benzole and not to the paraffine or olefine series. The basic oils also are allied to the benzoles. They form with the dilute acid solutions that may be used to wash them from the oils in which they may be dissolved, a reddish brown liquid. From this liquid they may be precipitated as cream colored flakes, which are hydrates of the basic radicals. If filtered off the precipitate soon changes color on the filter to a dark brown and on drying becomes nearly black. The acid tars also appear as hydrates. The acid hydrates are dark green, brown or black semi-solids, possessing extraordinary viscosity. The basic hydrates when deprived of their water yield brown or cherry-red oils which are very transparent and brilliant and which with the acid hydrates are much heavier than water. The entire series of basic radicals has not yet been isolated with certainty as to the higher members. It appears probable that the series commences with pyridin and embraces a large number of pyridins and chinolins, rising to compounds so dense that when left as a residue resembling coke, from distillation at a temperature near the red heat, they are still soluble in hydrochloric acid from which they may again be precipitated as hydrates in cream-colored flakes.

The discovery of these substances has led to very important changes in the technology of the bitumens in which they occur. Both the acid and basic radicals of the compound ethers are very easily removed from the distillates. The remaining oils are more easily susceptible to ordinary treatment with concentrated acids and alkalies, producing oils in every respect superior for their respective uses to those containing the basic radicals and tars, which it has been found the concentrated acid will only partially remove. The burning oils possess superior illuminating power and the lubricating oils are improved in color and are of greatly increased viscosity for corresponding degrees of specific gravity.

This discovery has also opened up a new source of supply to technology for the pyridin and chinolin bases and probably other allied substances not yet known to science. It is probable that not only pyridin and chinolin are present but that also a large number, if not all, of the methylated compounds of these bases are associated with them. The quality of the basic oils from this source is very superior, they being easily freed from the combination in which they exist in the native bitumens and their distillates.

This discovery is also of equal interest when made the subject of purely scientific speculation. The presence of these basic oils establishes beyond any question the animal origin of the bitumens in which they are found. I have tested all of the varieties of bitumen, from the most fluid petroleums to solid asphaltum, found in the region south of the line which forms the northern boundary of San Louis Obispo, Kern and San Bernardino Counties, and have invariably observed the reaction which indicates their presence. These varieties of bitumen include the petroleums found in the vicinity of Santa Paula, malthas from the same neighborhood, from near Los Angeles, from Carpinteria and from Asphalto on the north side of the Coast Ranges west of Bakersfield. I have not treated any of the oil from the vicinity of the Pico Spring directly for basic oils, but the large amount of nitrogen found on analysis of this oil in 1868, indicates the presence of these compounds. The determination of the percentage amounts of basic oils present in crude bitumens presents some difficulties not yet overcome.

A number of facts observed indicate that all those forms of bitumen that have been least exposed to the action of atmospheric oxygen, contain the largest proportion of basic oils. Analysis shows less nitrogen in the malthas and still less in the asphaltums, than in the petroleums. It appears that the compound ethers or *esters* which exist in the native petroleums are decomposed with substitution of oxygen for nitrogen. This substitution I have made artificially. The result is the pre-

cipitation of the acid radical as a hydrate within the oil, in which it dissolves, producing a viscous tar. When this decomposition has proceeded so far that water in appreciable quantity becomes a constituent of the compound, the bitumen is no longer petroleum but maltha. This water of hydration separates only when the maltha is heated to a comparatively high temperature. It will never separate by difference of specific gravity at comparatively low temperatures; but requires a temperature at which the hydrate is decomposed into a dense oil very much less viscous than the hydrate on the one hand and water on the other.

As the change proceeds the bitumen becomes solid asphaltum, and a new compound, that is found in maltha only in small quantity if at all, appears. This is Boussingault's *asphaltane*,* which was assumed by him to be an oxidized product in which oxygen was substituted for hydrogen. Recent experiments not yet completed indicate that asphaltene is not a simple substance, but that it may be resolved by suitable solvents into a compound containing oxygen and a compound that represents the original hydrocarbon, minus a portion of its hydrogen, by virtue of which it is no longer soluble in those fluids that dissolve the hydrocarbon in its original form.

The work that I have been able to accomplish since I first became aware of the existence of these substances in January last, as constituents of California bitumens, has been mainly technical. As related to purely scientific considerations it may be compared to the action of a skirmish line, which by drawing the fire of a vast army has revealed its presence. I am confident that the solution of problems of great importance to all of the varied technical applications of bitumen awaits the careful investigation of the nitrogen content of the immense accumulations of bitumen in all its forms found in California.

Perhaps it may be demonstrated, that the permanent asphaltic constructions of antiquity were made of asphalts of animal origin, consisting of hydrocarbons of the benzole series instead of those of vegetable origin, consisting of terpenes.

University of Michigan, Ann Arbor, Michigan, June 4th, 1894.

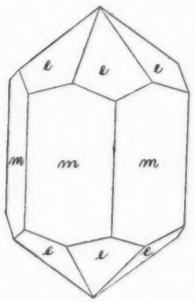
* Annales de Chemie et de Physique (2), lxiv, 141; Journal of the Franklin Institute, xxiv, 138; New Edinburg Philosophical Journal, xxii, 97.

Art. XXXV.—*Note on Artificial Crystals of Zinc Oxide;* by Heinrich Ries.

The occurrence of artificial crystals of zinc oxide in the reverberatory furnaces used in the manufacture of zinc white is not uncommon, but the crystals are usually rounded and their faces give poor reflections.

A number of good crystals have been described by foreign mineralogists,* but the only notice of those occurring in American furnaces is by G. A. Koenig,† who notes some crystals of artificial zinc oxide from the furnaces at La Salle, Ill. The needle-like character of the crystals, and their apparent hexagonal habit is commented on, but no measurements were made of them.

The writer recently received two lots of these crystals, one from Mr. D. A. van Ingen of the New Jersey Zinc and Iron Co., in Newark, N. J., and the other from Mr. G. F. Kunz who collected them at the works of the Passaic Zinc Co., in Jersey City, N. J. The crystals from Newark showed combinations of pyramid and prism, but the faces gave too poor reflections to permit identification. Among the lot from Jersey City were several crystals whose faces gave fairly satisfactory measurements. The following combinations were observed:



A first order prism and first order pyramid $\frac{2}{3}$; a first order prism and first order pyramid $\frac{1}{2}$; a first order prism *m*, and second order pyramid *e*, $\frac{1}{2}$–2. This last crystal was doubly terminated and holohedral. Second order pyramids are not common, and the writer has not seen the face *e* previously noted.

Both the natural and artificial zinc oxide are said to be hemimorphic in habit,‡ but none of the specimens examined could be said to have this habit. One crystal showed a tapering prism, low pyramid, and base. The crystals were colorless, transparent and without basal

* Koch: Beitr. z. Kenntniss Kryst. Hüttenprod.; Göttingen, 1822. Des Cloiseaux: Ann. d. Mines, 1842 (4), vol. i, p. 488. Lévy, Ann. Mines, iv, p. 516, 1843. G. v. Rath: Pogg. Ann. 1864, vol. 122, p. 406 and 1871, vol. 144, p. 580. A. Firket: Ann. Soc Geol. Belg. 1885, 12th Bull., p. 191. G. Greim: Ber. d. Oberhess. Ges. f. Nat. u. Heilk., 1886, vol. xxiv, p. 51. K. Busz: Zeitschr. f. Kryst. u Min. 1888–1889, vol. xv. J. T. Cundall: Min. Mag., vol. ix, no. 41, 1890. A. Hutchinson: Ibid., vol. ix, p. 5, 1890.

† Proc. Phila. Acad. Sci., 1873, p. 12.

‡ Dana, System of Mineralogy, 1892, p. 208.

cleavage. They were all of small size, those mentioned being respectively ·5×3, 1×2·5 and ·5×1·5 mm.

The pyramid $\frac{2}{5}$ was observed by Rinne, Greim and Cundall, and the pyramid $\frac{1}{2}$ by Lévy, Greim, Cundall and Hutchinson.*

The following are the angles measured and calculated; the former did not vary more than 20′ in each case.

	Angle measured	Angle calculated.
$I \wedge \frac{2}{5}$	54° 27′	53° 9′ 50″†
$I \wedge \frac{1}{2}$	43 47	42 5
$\frac{1}{2}$–2 $\wedge$ $\frac{1}{2}$–2	38 12	36 42

Mineralogical Laboratory, Columbia College.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Law and Theory in Chemistry;* a Companion book for Students. By Douglas Carnegie, M.A. 12mo, pp. viii, 222. London, 1894 (Longmans, Green & Co.).—This little book contains the substance of a summer school course of eight lectures delivered before an audience of school teachers of elementary chemistry at Colorado College, Colorado Springs. As its title indicates it is not intended as a text-book, but is offered as a *resumé* of the more important fundamental principles of chemistry which are less fully considered in ordinary manuals. The subjects treated are Alchemy, the Phlogistic Theory, Chemical Classification, the Atomic Theory, the Classification of Compounds, Isomerism and Molecular Architecture, and Chemical Equilibrium. These chapters are clearly and accurately written and the book will be a valuable aid to the earnest student. It is to be regretted that it is not provided with an index. G. F. B.

II. Astronomy.

1. *A Treatise on Astronomical Spectroscopy:* being a Translation of "Die Spectralanalyse der Gestirne," by Professor Dr. J. Scheiner, Assistant at the Royal Astrophysical Observatory at Potsdam. Translated, revised and enlarged, with the coöperation of the author, by Edwin Brant Frost, M.A., Assistant Prof. of Astronomy in Dartmouth College. 8°, pp. xiii, 482. Figs. 81; Pl. 2. Ginn & Co., Boston and London, 1894.—The novelty

* Previously cited.

† These values are based on Rinne's calculations. See Dana, Syst. of Min., 1892, p. 208.

and importance of recent spectroscopic work in Astrophysics ensured for the able and comprehensive survey of the subject, by so competent a writer as Dr. Scheiner, an immediate and cordial reception in astronomical circles, and gave it at once a recognized position as a standard treatise. The very rapid development of this branch of science since 1890, when this work was issued, has resulted in the accumulation of a great number of interesting discoveries, and thrown new light upon many important problems. This fact, as well as the desirability of making the work accessible to a wider circle of students and readers, afforded excellent reasons for a revision.

Professor Frost's translation follows the original text, in the main, very closely, especially in those portions where there has been comparatively little occasion for change. Additions have been liberally made, however, where necessary, and in some instances the newer material is of such a character as to supersede the older results and require a substantial recasting of the topics. Thus, in the chapter upon the motion of the stars in the line of sight, the remarkable application of photographic methods made by Vogel in 1892, giving values with a degree of precision hitherto unapproached, has necessitated the omission of the long list of star velocities determined at Greenwich, and the substitution therefor of Vogel's list of fifty-one stars made by the new method, while the excellent determinations made by other observers in a few cases have not been overlooked. Among other additions may be mentioned Rowland's determination of solar lines, his catalogue of standard lines, and his table of elements occurring in the sun; Young's table of chromospheric lines, corrected and extended by his recent observations; the extension of this catalogue into the ultra-violet region by Hale and Deslandres, and Hale's work upon the spectra of sun-spots and faculæ; recent discoveries of Huggins, Vogel, Keeler, and Campbell in respect to spectra of the nebulæ; Keeler's determinations of the motion of nebulæ in the line of sight; Langley's remarkable work upon the ultra-red region of the solar spectrum, and Abney's table of wave-lengths of solar lines in the ultra-red. Very great changes have been made also in the part relating to the spectra of stars of the different types, the amount of new matter added being very considerable, and well representing the work in this department to the date of publication. A very judicious change is the adoption of Rowland's scale of wave-lengths, unquestionably the most accurate now extant, and, in connection with his photographic charts, the most convenient for practical use.

The volume, as thus expanded, has but few pages more than the original work, owing not only to the slightly larger and more compactly printed page employed, but also, as explained by the author, to the fact that the English saves in space nearly one page for every ten of the German in translation. Professor Frost has executed his task very skillfully, and has shown excellent judgment in the selection and co-ördination of the new material. The style is clear and flowing, and remarkably free from the stiffness and awkwardness so difficult of avoidance in a translation.

A. W. W.

APPENDIX.

Art. XXXVI. — *Description of Tertiary Artiodactyles;* by O. C. Marsh.

The main object of the present paper is to figure, and to describe more fully, several interesting ungulate mammals, which have been previously named and noticed by the writer. A number of others, mostly allied forms, are here described for the first time. The specimens discussed are chiefly from the western part of the country. Some of them from the Miocene, however, are apparently identical with those found on the Atlantic coast, and thus for the first time it is possible to make out a definite horizon in the Tertiary, extending nearly across the continent.

Eocene Bunodont Artiodactyles.

The Artiodactyles known from the Eocene of this country are few in number, and nearly all small generalized forms. The oldest hitherto found appear to have suilline affinities, but the others cannot be placed with any certainty in any of the existing groups. The first Artiodactyles, so far as now known, are preserved in the lower Eocene, in the horizon named by the writer the "Coryphodon beds," and these are all primitive forms. In the middle Eocene, especially in the "Dinoceras beds," the remains of these mammals are more abundant, and some of them permit accurate determination. In the upper Eocene, in the Diplacodon horizon, more specialized forms occur, and for the first time resemblance to several modern types can be recognized.

Eohyus distans, sp. nov.

The present genus was proposed by the writer in 1877, in an address before the American Association for the Advancement of Science.* In reviewing the extinct ungulates of this country, the following statement was then made in regard to the present group:—

* Introduction and Succession of Vertebrate Life in America, this Journal, vol. xiv, p. 362, 1877.

"The Artiodactyles, or even-toed Ungulates, are the most abundant of the larger mammals now living; and the group dates back at least to the lowest Eocene. Of the two well marked divisions of this order, the Bunodonts and the Selenodonts, as happily defined by Kowalevsky, the former is the older type, which must have separated from the Perissodactyle line after the latter had become differentiated from the primitive Ungulate. In the Coryphodon beds of New Mexico, occurs the oldest Artiodactyle yet found, but it is at present known only from fragmentary specimens. These remains are clearly Suilline in character, and belong to the genus *Eohyus*. In the beds above, and possibly even in the same horizon, the genus *Helohyus* is not uncommon, and several species are known."

The type specimen of the genus *Eohyus* is represented below, natural size, in figure 1. Various other remains have been found, which might be referred to this species, but they give but little definite information as to its affinities, since it is not certain that the reference is correct. The type specimen is a last upper molar, and the characters of its crown are well shown in the figure. Another upper molar shows the same essential features. Judging from these specimens alone, the animal would appear to have been a suilline, or at all events, a bunodont Artiodactyle. Future discoveries must determine its exact position. With the specimens described next below, the present remains represent a distinct family, which may be called the *Eohyidæ*.

Eohyus robustus, sp. nov.

A larger species, which may be referred provisionally to the genus *Eohyus*, is represented by portions of a pair of lower jaws with imperfect teeth, and fragments of other specimens. The teeth are tubercular, and agree sufficiently well with the type of the genus to be regarded as belonging to an allied species. The lower jaws are very short and robust, with a strong symphysis. There were apparently four lower premolars and three molars, forming a continuous series, measuring about three inches in length. The depth of the jaw below the first true molar was one inch. The remains representing this species are from the lower Eocene of New Mexico.

Various remains of animals with a dentition resembling that of suillines have been described by Cope under the generic name *Periptychus*, which is preoccupied. These remains are from the so-called Puerco deposits, or lower Wahsatch of New Mexico, a horizon lower than that in which the type of *Eohyus* was discovered.

Parahyus aberrans, sp. nov.

In figure 2 below, a last upper molar tooth is represented natural size, which may be referred to the present genus, described in 1876.* There can be little doubt that the type species, as well as the present tooth, belonged to suilline mammals, although they indicate animals much larger than would be expected from so low a horizon. Moreover the type had but three lower premolars, and thus was more specialized than most of the ungulates from the same horizon.

The present specimen resembles somewhat the last upper molar of *Homacodon*, but shows distinct indications of a third posterior cone on its inner margin. This specimen was found in the Coryphodon beds of Wyoming, near the locality where the type of *Parahyus vagus* was discovered. It represents an animal about half as large as the type of the genus.

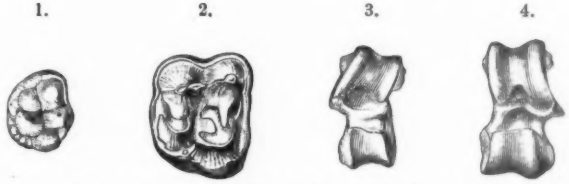


FIGURE 1.—Last upper molar of *Eohyus distans*, Marsh; seen from below.
FIGURE 2.—The same tooth of *Parahyus aberrans*, Marsh; seen from below.
FIGURE 3.—Astragalus of *Homacodon priscus*, Marsh: front view. All three figures are natural size.
FIGURE 4.—Astragalus of *Homacodon pucillus*, Marsh; front view. Twice natural size.

Homacodon priscus, sp. nov.

Among the undoubted Artiodactyles of the lower Eocene are two species which cannot at present be separated from the genus *Homacodon*. The astragalus of one of these is represented above in figure 3, and a second smaller species, *H. pucillus*, in figure 4. The other known remains of these two species are not distinctive, but indicate true Artiodactyles of the bunodont type, and are interesting mainly from proving the existence of such forms in the lower Eocene. They occur in the Coryphodon beds of Wyoming and New Mexico.

Teeth resembling those of *Helohyus* are likewise found in this horizon, but it is not certain that they pertain to true Artiodactyles. Some have been referred to the Perissodactyles. Others may belong to the *Mesodactyla*.

*This Journal, vol. xii, p. 402, November, 1876.

Homacodon vagans, 1872.

In the Dinoceras beds of the Bridger basin, in Wyoming, which may be regarded as middle Eocene, various remains of Artiodactyles have been found, but none with the selenodont dentition. All yet discovered still belong to the bunodont division of *Artiodactyla*, and most of these are small in size. The first genus discovered and described was *Homacodon*, and the type specimen is the most perfect of the group yet found.* In figures 5 and 6 below, the upper and lower molar teeth of this specimen are represented, and in figures 7 and 8, the distal end of the tibia and the astragalus of the same individual are also shown, all twice natural size.

5.

6.

FIGURE 5.—Upper molar series of *Homacodon vagans*, Marsh; (type) seen from below.

FIGURE 6.—Lower series of same individual; seen from above.

Both figures are twice natural size.

The present genus has apparently the complete dentition, forty-four teeth, although the type specimen does not reveal the exact number of incisors. The canines are large. The anterior premolars, above and below, are secant. The last upper premolar has a single outer cusp and one inner cone. The upper molars have each two conical external cusps. There is a small median anterior cusp, also, on each. The first molar has three posterior cusps, all well developed. The second molar has the inner posterior cusp small, and in the third molar, this is wanting, or only represented by the basal ridge from which the others were derived.

The skull of the type specimen of the present species has a brain case of fair size, and a sharp sagittal crest. The orbits are not closed behind. The cervical vertebræ are short, and have their ends oblique, indicating a curved neck. The dorsals are of moderate length, with the centra broad, and their ends flat. The posterior trunk vertebræ are all keeled below.

* This Journal, vol. iv, p. 126, August, 1872.

There appear to have been five digits in the manus, and the same number in the pes, although probably only four were functional. The animal was about the size of a small rabbit.

The present genus with the one next described represent a distinct family, which may be called the *Homacodontidæ*.

After the establishment of the genus *Homacodon*, by the writer, in 1872, Cope proposed the name *Pantolestes* for a small animal from essentially the same horizon. The type was a lower jaw, with the teeth too imperfect for exact determination, but the animal was referred to the Lemuroids.* This reference was subsequently strengthened by Cope, who placed this specimen in the genus *Notharctus* of Leidy, with *Pantolestes* as a synonym.† Afterwards he revived the name *Pantolestes*, and placed under it remains of Artiodactyles, some evidently pertaining to the genus *Homacodon*, and later still he included other species, but none of them apparently distinct from that genus.

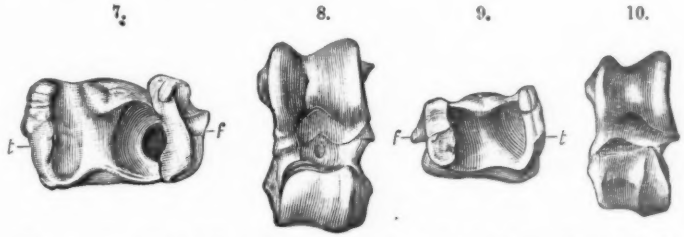


FIGURE 7.—Tibia of *Homacodon vagans*; (type) distal end. *t*, tibia; *f*, fibula.
FIGURE 8.—Astragalus of same individual; front view.
FIGURE 9.—Tibia of *Nanomeryx caudatus*, Marsh: distal end.
FIGURE 10.—Astragalus of same species; front view.
All the figures are twice natural size.

Nanomeryx caudatus, gen. et sp. nov.

This genus appears to be nearly related to *Homacodon*, with which it agrees in several respects, but may be distinguished from it by the fact that the fibula is reduced, and coössified distally with the tibia. The lower jaws are more slender and compressed than in *Homacodon*, and there is a short diastema between the canine and first lower premolar. The bones of the skeleton, even the vertebræ, are very hollow.

* Proc. Amer. Philos. Soc., vol. xii, p. 467, for 1872.
† Sixth Ann. Rep. U. S. Geol. Surv. Terr., p. 549, 1873.

The humerus is perforated above the lower condyle, and the inner condylar margin is without the process characteristic of *Homacodon*. The radius and ulna are separate, but the latter bone is quite slender. The fibula is incomplete. The lower part has coalesced entirely with the tibia, but the suture remains distinct, except in very old individuals. In figures 9 and 10, the distal end of the tibia and the astragalus of this species are represented twice natural size.

The present species is only about half as large as *Homacodon vagans*, and is thus one of the smallest Eocene Artiodactyles known. The first specimens discovered were found by the writer in 1870, near Fort Bridger, Wyoming. The type specimen here described is from the same region. All are from the Dinoceras beds of the middle Eocene.

Helohyus plicodon, 1872.*

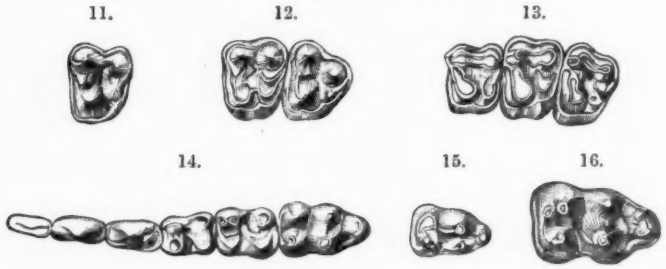


FIGURE 11.—Last upper molar of *Helohyus plicodon*, Marsh; (type) seen from below.

FIGURE 12.—Second and third upper molars of same species.

FIGURE 13.—Three worn upper molars of same.

FIGURE 14.—Lower teeth of same.

FIGURE 15.—Last lower molar of *Helohyus* (*Thinotherium*) *validus*, Marsh; top view.

FIGURE 16.—The same tooth of *Helohyus* (*Elotherium*) *lentus*, Marsh.

All the figures are natural size.

The genus *Helohyus*, as at present known, includes several species of suilline mammals, all much larger than those of *Homacodon*, and most of them, at least, from a higher horizon of the middle Eocene. The type specimen of the present species, which is also the type of the genus, includes the last upper molar represented natural size, in figure 11 above. This is in fine preservation, and shows clearly the characteristic features of the crown. Other remains found with the type, and still others from the same locality or horizon, give more characters of the genus, although no single skeleton is known

* This Journal, vol. iv, p. 207, September, 1872.

as complete as that of *Homacodon*. Figure 12 above shows the second and third upper molars of the present species; figure 13, three upper molars of an old animal; and figure 14, the lower teeth, all natural size. The astragalus is well shown in figure 17. The upper molars resemble those of *Homacodon*, but differ in having but two posterior cones.

17.

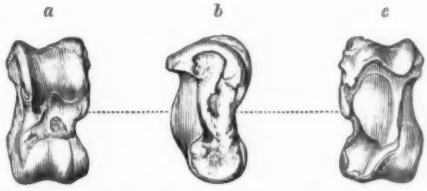


FIGURE 17.—Astragalus of *Helohyus plicodon*. Natural size. *a*, front view; *b*, side view; *c*, back view.

Two other species which probably should be referred to the present genus are *Thinotherium validum* and *Elotherium lentum*, described by the writer from specimens found in the same region as the type of *Helohyus*. The last lower molar of each is shown in figures 15 and 16. It is quite possible that another allied species was described by the writer under the name *Stenacodon rarus*, but at present the exact relationship between these forms cannot be determined. All are from the middle Eocene of Wyoming.

EOCENE SELENODONT ARTIODACTYLES.

In the autumn of 1870, the writer explored a new Tertiary lake-basin, which he had discovered south of the Uinta mountains, in Utah. This exploration was carried on with great hardship and much danger from hostile Indians, but proved conclusively that this lake-basin was of late Eocene age, and it was subsequently named by the writer, the Uinta basin. The first results of this exploration were published in an article "On the Geology of the Eastern Uinta Mountains,"* a paper that appears to have been overlooked by several recent writers on the subject. This Eocene lake-basin was quite distinct from the older Bridger basin, north of the Uinta mountains, which the writer also first explored in 1870. These researches further resulted in securing many new vertebrate fossils from each basin. The two were later distinguished by the writer, by names taken from the largest and most characteristic animals found in them. The strata of the Uinta basin were thus named the "Diplacodon beds," and those of the northern lake deposits, the "Dinoceras beds."

* This Journal, vol. i, p. 191, March, 1871.

Eomeryx pumilus, Marsh.

Among the interesting fossils found by the writer in the Uinta basin, in 1870, were remains of three small Artiodactyles, each with selenodont dentition, the earliest then known in the country. One of these animals was described under the name *Agriochœrus pumilus*,* as the lower teeth and other portions secured resembled strongly the corresponding parts pertaining to that genus, as known from a higher horizon. Subsequent discoveries proved that these remains were distinct from those of *Agriochœrus*, the upper molars resembling more nearly those of *Ancodus* (*Hyopotamus*), but in reality representing a new genus, which was named by the writer *Eomeryx*, in the address already cited.†

18.

FIGURE 18. — Upper teeth of *Eomeryx pumilus*, Marsh; seen from below. Natural size.

In the address quoted, the writer defined the Uinta Artiodactyles with selenodont dentition, as follows: "In the *Diplacodon* horizon of the upper Eocene, the Selenodont dentition is no longer doubtful, as it is seen in most of the *Artiodactyla* yet found in these beds. These animals are all small, and belong to at least three distinct genera. One of these, *Eomeryx*, closely resembles *Homacodon* in most of its skeleton, and has four toes, but its teeth show well marked crescents, and a partial transition to the teeth of *Hyopotamus*, from the Eocene of Europe. With this genus, is another (*Parameryx*), also closely allied to *Homacodon*, but apparently a straggler from the true line, as it has but three toes behind. The most pronounced Selenodont in the upper Eocene is the *Oromeryx*, which genus appears to be allied to the existing Deer family, or *Cervidæ*, and if so is the oldest known representative of the group. These facts are important, as it has been supposed, until very recently, that our Eocene contained no even-hoofed mammals." Again in speaking of the Oreodonts in the Miocene, the following statement is made: "The least specialized, and apparently the oldest, genus of this group is *Agriochœrus*, which so nearly resembles the older *Hyopotamus*, and the still more ancient *Eomeryx*, that we can hardly doubt that they all belonged to the same ancestral line."

* This Journal, vol. ix, p. 250, March, 1875.
† *Ibid.*, vol. xiv, p. 364, November, 1877.

By subsequent researches in the Uinta basin, the writer secured many additional remains of all these three Artiodactyles, and in regard to *Eomeryx*, at least, nearly all the important characters can thus be determined. These specimens confirm in a decisive manner the original determination of the essential features and affinities of the animal described from the first fragmentary remains.

The skull of *Eomeryx* has the same general form as that of *Agriochœrus*, and the lower jaw and dentition are essentially the same. As in that genus, there is no lachrymal fossa, and the orbit is not closed behind. The complete dentition of forty-four teeth is a primitive character to be expected from a horizon lower than that of *Agriochœrus*. In this respect and in several others, especially in the feet, *Eomeryx* shows a nearer relationship to *Oreodon*, with which it certainly has strong affinities.

The upper molars, as shown above, natural size, in figure 18, have the characteristic fifth lobe on the front of the crown, as in the *Ancodontidæ*, or *Hyopotamus* family, and this feature alone, given in the original description of the genus, served to distinguish *Eomeryx* from any allied forms in the strata in which it was found. The lower molars are shown in figure 22.

19.

FIGURE 19.—Upper teeth of *Hyomeryx breviceps*, Marsh; seen from below. Natural size.

The limbs and feet of *Eomeryx* are of much interest. The radius and ulna are distinct, and of nearly equal size. There are four functional digits in the manus, and the first was also represented, although of little use. In the hind limbs, the fibula was slender, but complete. There were four functional toes in the pes, all well developed, and a remnant, at least, of the first was present. The digits were terminated by narrow hoofs, similar to those in *Oreodon*.

The genus *Eomeryx*, as thus determined, clearly represents a distinct family, which may be called the *Eomericidæ*. This group includes the genus *Hyomeryx*, described below, and contains the oldest selenodont suillines in this country. It had for its predecessors *Helohyus* and *Homacodon* from the strata of the Dinoceras beds.

The present genus and species, *Eomeryx pumilus*, were redescribed by Scott and Osborn, in 1887, under the name *Protoreodon parvus* (Proc. Amer. Philos. Soc., vol. xxiv, p. 257), and later, in 1889, by Scott, more in detail (Trans. Amer. Philos. Soc., vol. xvi, p. 487). No reference was made in either paper to the article by the writer, cited above, relating to the Uinta basin, and the statements made concerning the first researches in the basin are inaccurate. The description and figures are in the main correct.

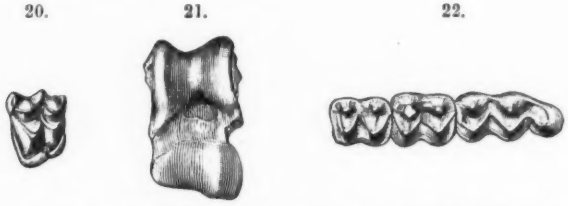


FIGURE 20.—Upper molar of *Parameryx lævis*, Marsh; seen from below.
FIGURE 21.—Astragalus of same species; front view
FIGURE 22.—Lower molars of *Eomeryx* (*Agriochœrus*) *pumilus*; top view.
The figures are all natural size.

Hyomeryx breviceps, gen. et sp. nov.

The present genus is nearly allied to *Eomeryx*, but represents a more specialized form. The skull is shorter, particularly in the facial region, but the most important difference is seen in the premaxillaries. In the present type, these are very much reduced, and thoroughly coössified with the maxillaries. They cover the canines in front, but contain no incisors. The upper canines are smaller than those of *Eomeryx*, and the maxillaries containing them are less robust. There is a diastema behind the upper canine, and the molars agree in form with those of *Eomeryx*. The lower jaws have the full dentition, the first premolar being caniniform, as in *Eomeryx* and *Oreodon*, but the lower jaws are less massive than in those genera, especially in front. Figure 19 shows the upper teeth of the type specimen.

There appear to be four functional digits in the fore feet, and the first is probably represented in a much reduced form. In the hind feet, also, there are four functional digits, and a remnant of the fifth is still retained.

The type specimen of the present genus is from nearly the same horizon as the type of *Eomeryx*. The present species was about two-thirds the size of *Eomeryx pumilus*.

Parameryx lævis, sp. nov.

The second genus of selenodont ungulates referred to in the address quoted is quite distinct from *Eomeryx*, but is known from less perfect remains. It may readily be distinguished from that genus by the upper molars that lack the extra fifth cone, and by the slender, compressed lower jaws, without a caniniform first premolar. The limbs and feet, also, show important differences. In the hind feet, there were but two functional digits, although the second was present in a reduced form. An upper molar and the astragalus of this species are shown in figures 20 and 21.

In size, the present species was smaller than the type of *Eomeryx*, and of more slender proportions. There appear to be one or two species of the present genus besides the type. One of these may be distinguished by the lower jaws, which have a deep groove on the inner face of the ramus, extending forward nearly to the symphysis. This form may be known as *Parameryx sulcatus*.

In the address already quoted, this genus was regarded as possibly related to the Camels and Llamas, but until additional remains are found, its exact affinities must remain in doubt.

In the two publications above cited, Scott and Osborn have given the name *Leptotragulus* to certain Artiodactyle remains from the Uinta deposits, but it does not appear from the descriptions or figures, that the specimens described are distinct from those on which the genus *Parameryx* was established. Some of them are apparently identical, although the species may be different. Others may pertain to *Oromeryx*, a genus certainly distinct from *Leptotragulus*, as described.

Oromeryx plicatus, sp. nov.

23.

FIGURE 23.—Upper teeth of *Oromeryx plicatus*, Marsh; seen from below. Natural size.

The third genus of Artiodactyles with selenodont dentition found in the Uinta basin by the writer, and noticed in the address above quoted, is *Oromeryx*. This genus is represented by numerous remains, many of them in good condition, which afford characters for distinguishing it from those above described. They represent, moreover, animals somewhat smaller in size than those already noticed, and of proportions still more delicate.

The skull in the frontal region is broad and flat. The supra-orbital foramina are widely separated, with diverging grooves leading to them from the nasal suture. The upper molars have oblique crowns, with no antero-median cusp. The upper molar teeth are especially characteristic, as seen from those represented natural size, in figure 23 above. The enamel of the crowns is finely wrinkled, and this has suggested the specific name. This feature is seen also in the lower molars, especially in the teeth of animals not fully adult. The lower jaws are slender, and compressed in front, and there is no diastema in the dentition.

The bones of the skeleton are very hollow. The humerus is perforated above the distal condyle. The ulna is complete. The fibula is also complete, with the distal end much compressed. There are four functional digits in the manus, and possibly five. There are four usable digits, also, in the hind feet, with the lateral ones well developed.

The affinities of this genus, as already stated, appear to be with the Deer family, and it also has some points of resemblance to the Traguloids.

Miocene Artiodactyles.

24.

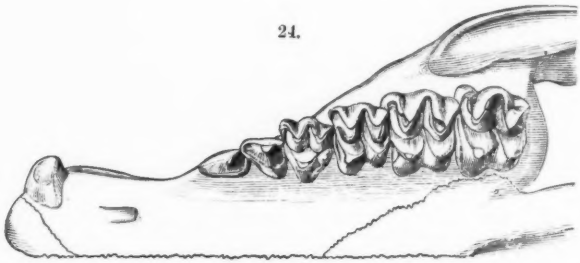


Figure 24.—Upper teeth of *Agriomeryx migrans*, Marsh; seen from below. Two-thirds natural size.

Agriomeryx migrans, gen. et sp. nov.

The present genus is most nearly related to *Agriochœrus*, Leidy, and appears to be its direct successor in a higher horizon of the Miocene. The two genera may be readily distinguished by the teeth. The older form has four premolars above and below, while *Agriomeryx* has but three. In figure 24 above, the left upper dental series of this species is shown two-thirds natural size. There are no upper incisors in the present genus. The lower jaws contain a full series of teeth,

twenty-two in number. The first lower premolar has assumed the form and function of a canine, the true lower canine being quite small, and resembling the incisors. The type specimen figured is from the Protoceras horizon in South Dakota.

Thinohyus, 1875.*

25. 26. 27.

FIGURE 25.—Last upper molars of *Thinohyus socialis*, Marsh; seen from below.
FIGURE 26.—Last upper molar of *Thinohyus lentus*. Marsh.
FIGURE 27.—Second lower molar of *Thinohyus antiquus*, Marsh; top view.
All the figures are natural size.

28.

FIGURE 28.—Lower teeth of *Thinohyus nanus*, Marsh; top view. Natural size.

Thinohyus nanus, sp. nov.

The present species is the smallest of the genus yet discovered. The specimen selected as the type is represented in figure 28 above, natural size. It is a left lower jaw, with the third and fourth premolars and the three molars in place. The front of the jaw is not preserved, but the alveole of a large canine is present, and also those of the first and second premolars, which were evidently secant. There was apparently no diastema behind the canine, and the whole jaw was unusually short and robust. The type specimen is from the Miocene of South Dakota, but the exact horizon is not known.

Two other species of the present genus, from the Miocene of Oregon, have already been described by the writer, and in figures 25 and 26 typical specimens of both are shown. The largest species is *Thinohyus* (*Dicotyles*) *antiquus*, from the same horizon in New Jersey, and the type is shown in figure 27.

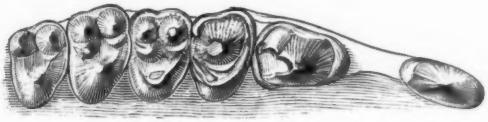
Leptochœrus gracilis, sp. nov.

The genus *Leptochœrus* was established by Leidy in 1856, the type specimen being the fragment of a small lower jaw containing two molar teeth, supposed to pertain to a suilline mammal.† Other remains subsequently referred to the same genus threw no additional light on the affinities of the animal, which up to the present time have remained in doubt.

* This Journal, vol. ix, p. 248, March, 1875.
† Proc. Acad. Nat. Sci. Phila., p. 88, 1856.

A specimen in the Yale Museum representing a different species, apparently pertains to the same genus, and proves, moreover, that the original suggestion as to the nature of the animal was probably correct. This specimen is in fine preservation, and consists of the skull and greater portion of the skeleton of an adult individual about as large as a rabbit. One interesting feature of the skull is the comparatively large size of the brain cavity, and the cast it contains shows well-marked convolutions. The dentition is of special interest. The upper molars resemble those of *Helohyus*, especially the last molar of that genus. They have each two outer cones, a single large inner cusp, and two intermediate lobes, the anterior uniting by wear with the inner cusp so as to form a crest. The fourth premolar has a single outer cone and one inner cusp. The third premolar is very large, and subtriangular in outline. The second premolar is secant, and behind it is a well-marked diastema. The teeth are shown in figures 29 and 30 below.

29.



30.

FIGURE 29.—Upper teeth of *Leptochœrus gracilis*, Marsh; seen from below.
FIGURE 30.—Lower teeth of the same skull; top view.
Both figures are twice natural size.

The lower jaws in the present species are slender, especially in front. The lower molars are very small, decreasing in size to the last. The fourth premolar is larger than the first molar. The anterior premolars are secant, and there is a diastema in front and behind the second. There is a deep groove on the inner side of the lower jaw, extending from the dental foramen nearly to the symphysis.

The radius and ulna are separate, and the latter well developed. There were apparently four functional digits in the manus. The fibula is much reduced. Its lower portion has coalesced with the tibia. The hind foot resembles that of *Homacodon*, having four usable digits, but the navicular and cuboid are coössified, an unexpected feature.

These remains prove that the animal they represent belonged to a distinct family, which may be called the *Leptochœridæ*. The type specimen of the present species is from the Miocene of South Dakota.

Calops cristatus, 1894.

The peculiar Artiodactyle described under the above name, in a late number of this Journal (p. 94), had many features of interest besides those mentioned in the original description. Some of these are as follows:

The brain was comparatively well developed, and an unusually large part of the cerebral lobes was covered by the parietals. The frontal region of the skull between the orbits was more or less concave. The antorbital depressions extend well forward. There is a diastema between the upper canine and the first premolar, and between the first and second premolars. The canines above and below are small. The first lower premolar appears to be wanting. The second and third premolars have secant crowns, much elongated fore and aft. The postglenoid process is quite small, but the paroccipital is large and robust. The lower jaw has a very short coronoid process, and the condyle is sessile. The angle of the jaw is well rounded and somewhat dependent.

PLIOCENE ARTIODACTYLES.

31. 32.

FIGURE 31.—First and second lower molars of *Platygonus rex*, Marsh; top view.
FIGURE 32.—Last lower molar of same species; young tooth; top view.
Both figures are natural size.

Platygonus rex, sp. nov.

The present species is the largest of the genus yet discovered. The type specimen is represented natural size, in figure 31 above. In figure 32, a last lower molar of the same species is shown, but it is a young tooth which had not yet come into wear. The peculiarity of these molar teeth, aside from their size, is that the crowns are mainly composed of well-rounded, conical tubercles, few in number, and placed systematically. The crowns of the first and second molars are each composed of four large cones, nearly equal in size, and the last molar has five.

This simplicity of structure is characteristic of the Eocene suillines, as already shown in the present article. In lower Miocene forms, it is less distinct. The type specimen of the present species and other remains were obtained by the writer, in 1871, from the Pliocene deposits of eastern Oregon.

Procamelus altus, sp. nov.

In the same horizon in eastern Oregon in which is found the peccary last described, remains of a very large extinct camel also occur. Various portions of the skull and skeleton were secured by the writer, and these all appear to pertain to the genus *Procamelus*, as described by Leidy. These remains indicate a camel exceeding in size any previously described from this country, and one in which the extremities were especially elongated. In figures 33 and 34 below, the calcaneum of this animal is represented one-fourth natural size. The known remains of this species are from the Pliocene deposits, near the John Day River, in Oregon.

33. 34.

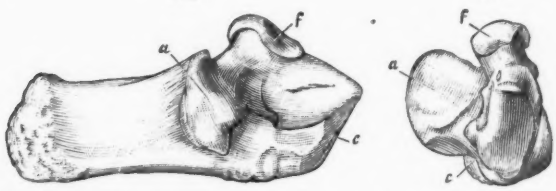
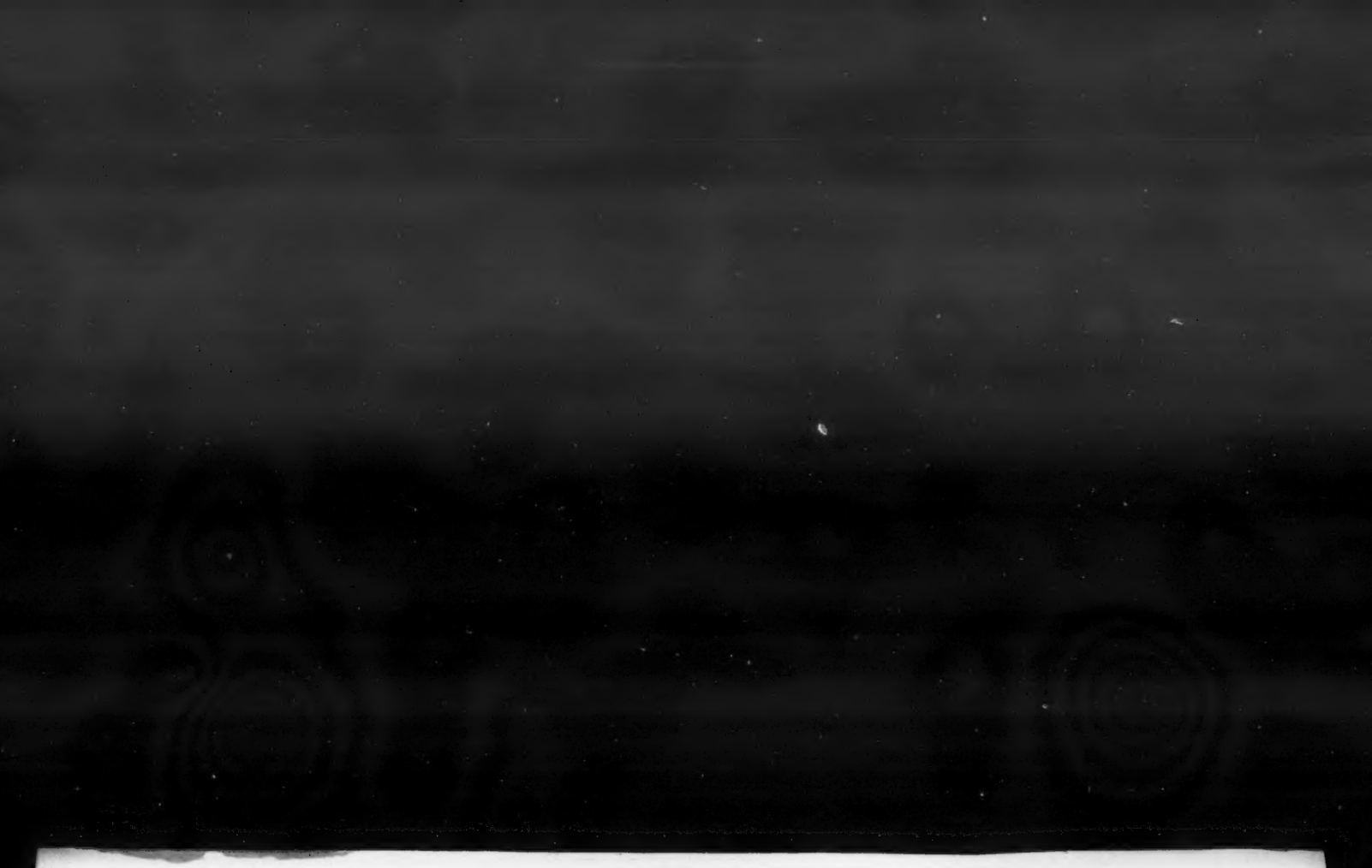


FIGURE 33. – Left calcaneum of *Procamelus altus*, Marsh; inner view.
FIGURE 34.—The same bone; front view. Both figures are one-fourth natural size. *a*, face for astragalus; *c*, face for cuboid; *f*, face for fibula.

CORRELATION OF MIOCENE HORIZONS.

In the July number of this Journal, the writer made the announcement that the horizon in the Miocene deposits of Oregon, which he had explored many years since, and named the Miohippus beds, was also represented east of the Rocky Mountains, and in the same relative position, various vertebrate fossils being common to both. In a previous number of the Journal (November, 1893), the writer had stated that a distinct horizon in the Miocene on the Atlantic coast, named by him the Ammodon beds, corresponded to one in the Rocky mountain region, in which the same genus, *Ammodon*, had been found. More recent researches have brought out the interesting fact that this horizon is essentially the same as the Miohippus beds of the central region, and as those on the Pacific coast as well, so that at last a definite horizon is determined in the Miocene, extending across the continent.

Yale University Museum, New Haven, Conn., August 15, 1894.



NEW AND BEAUTIFUL MINERALS!

A GREAT STRIKE AT THE TILLY FOSTER MINE!

Two visits were made during the past month to this mine and the finest specimens of **Clinochlore** (Ripidolite) ever found in this country were secured. We purchased the pick of all the local collections, and bought up many individual specimens of the miners. The Clinochlores are commonly in groups of large, tabular, hexagonal crystals inserted edgewise on the matrix, their brilliancy and deep, rich green color making them unusually attractive. Good loose crystals as low as 10c.; fine groups, 50c. to $5.00. **Chondrodite,** very choice specimens with crystals uncommonly sharp and brilliant, 50c. to $5.00; good **Brucites,** well crystallized, 25c. to $2.00; excellent **Serpentine Pseudomorphs,** 25c. to $1.00.

Onegite, or Quartz enclosing brilliant deep-red needles of Göthite, a very rare combination, heretofore found, we believe, only at Onega, Russia, has just been obtained from Colorado, in exceedingly fine specimens. Polished sections of Amethystine and Smoky Quartz crystals, occasionally exhibiting phantoms, 50c. to $5.00.

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Sulphurs! Another box of still finer specimens just in, 25c. to $2.50; large groups $3.50 to $10.00.

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